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**FINAL
CORRECTIVE ACTION PLAN WITH
BIOVENT PILOT TEST RESULTS,
UST SITE 43402
Revision 1
September 26, 2005**

**MARINE CORPS BASE
CAMP PENDLETON, CALIFORNIA**

DCN: SES-TECH-05-0126

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ABBREVIATIONS AND ACRONYMS

µg/L	micrograms per liter
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene and total xylenes
CAP	Corrective Action Plan
DEH	Department of Environmental Health
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
FWENC	Foster Wheeler Environmental Corporation
IT	International Technology Corporation
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
MTBE	methyl tert-butyl ether
NAVFAC SW	Naval Facilities Engineering Command, Southwest
ORC [®]	Oxygen Release Compound
ORP	oxygen/reduction potential
PAH	polynuclear aromatic hydrocarbon
PVC	polyvinyl chloride
RWQCB	Regional Water Quality Control Board
scfm	standard cubic feet per minute
SES-TECH	Sealaska Environmental Services LLC and Tetra Tech EC, Inc.
SPLP	Synthetic Precipitation Leaching Procedure
TEP	tri-ethyl phosphate
TPH-d	total petroleum hydrocarbons quantified as diesel
TPH-g	total petroleum hydrocarbons quantified as gasoline
TtFW	Tetra Tech FW, Inc.
UST	Underground Storage Tank
VOC	volatile organic compound
WQO	Water Quality Objective

1.0 INTRODUCTION

This Corrective Action Plan (CAP) for Underground Storage Tank (UST) Site 43402, Marine Corps Base (MCB) Camp Pendleton, California (Figure 1-1), was revised by SES-TECH, a joint venture between Sealaska Environmental Services LLC and Tetra Tech EC, Inc. (formerly Tetra Tech FW, Inc.), pursuant to a request by the California Regional Water Quality Control Board, San Diego Region (RWQCB) in a letter dated February 1, 2005 (reference: SMC: 50-3592.05:peurp). The original CAP was prepared by Tetra Tech FW, Inc. and the RWQCB requested the CAP focus more on the soil impacts reported in the saturated zone. Besides including more discussion on the soil impacts below the water table, this revised CAP includes the results of long-term bioventing of vadose zone soils, results of additional groundwater sampling completed in 2004 and 2005, and the results of soil confirmation sampling completed to evaluate the progress of the biovent system. This CAP was revised under the Naval Facilities Engineering Command, Southwest (NAVFAC SW) Contract No. N68711-04-D-1104, Contract Task Order No. 0004.

1.1 SITE IDENTIFICATION

The following list summarizes site identification data:

Site Address:	Building 43402, 43 Area MCB Camp Pendleton, CA 92055
Facility Name:	Mess Hall
RWQCB Case No.:	9UT3592
County of San Diego Department of Environmental Health (DEH) Case No.:	H05939-059
Property Owner and Responsible Party:	United States Marine Corps
MCB Camp Pendleton Contact:	Mr. Chet Storrs, Remediation Branch Manager Assistant Chief of Staff, Environmental Security Building 22165 MCB Camp Pendleton, CA 92055-5008 (760) 725-9774
Remedial Project Manager:	Mr. Bipin Patel NAVFAC SW 1220 Pacific Highway San Diego, CA 92132-5181 (619) 532-4814

1.2 OBJECTIVES

The primary objectives of this CAP are as follows:

- Summarize the site history and assess the impacts of contamination detected in soil and groundwater.
- Identify and evaluate relevant potential corrective action alternatives.
- Provide a recommendation regarding the most appropriate corrective action alternative for the site.
- Meet the requirements of the California RWQCB and the San Diego County DEH Land and Water Quality Division for the submittal of a CAP.

UST Site 43402 is regulated under the California State Water Resources Control Board Leaking Underground Fuel Tank program as administered by the RWQCB, San Diego Region. The document guiding the assessment, remediation, and closure process for the site is the *San Diego County Site Assessment and Mitigation Manual 2005* (DEH, 2005).

The overall purpose of this CAP is to identify and evaluate remedial alternatives for effectively and appropriately addressing contamination at UST Site 43402 and to provide a recommendation regarding corrective action at the site. This CAP contains seven sections, including this introduction as Section 1.0. Section 2.0 includes a description of the site and a summary of previous site activities. Section 3.0 includes an assessment of current soil and groundwater impacts, and Section 4.0 proposes site cleanup goals. Section 5.0 develops a list of alternatives that are appropriate for the site and presents evaluations on their effectiveness, implementability, and cost. A recommendation on the most preferred alternative is included in Section 6.0, and a list of references used to prepare this CAP is included in Section 7.0.

2.0 SITE DESCRIPTION AND HISTORY

The following sections provide a brief description of the site and a summary of previous activities.

2.1 SITE DESCRIPTION

Site 43402 is located on C Street, in the 43 Area of MCB Camp Pendleton (Figure 1-2). Building 43402 is a mess hall and once contained a 6,000-gallon single-walled steel UST used to store diesel fuel for heating. The former UST was located behind Building 43402 in a relatively flat, asphalt and concrete-paved area adjacent to a loading dock.

2.2 EXPLORATORY DRILLING

Between November 1991 and February 1992, two soil borings were drilled and three groundwater monitoring wells were installed at the site [International Technology Corporation (IT), 1993]. The soil borings and monitoring wells were sampled up to 35 feet below ground surface (bgs). Analytical results from soil samples indicated that total petroleum hydrocarbons quantified as diesel (TPH-d), and total recoverable petroleum hydrocarbons were present in soil near the tank cavity extending down from approximately 15 feet bgs to the groundwater table at approximately 30 feet bgs. Results from groundwater samples collected from the monitoring wells indicated that TPH-d and volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene and total xylenes (BTEX), were not present in the groundwater. However, based on comments by the RWQCB, the sample data from these wells were considered inconclusive because the screened intervals of the wells were below the water table. Consequently, all three groundwater monitoring wells were destroyed in 1997 (Brown and Caldwell, 1999). Figure 2-1 presents the analytical results and locations of the soil borings and groundwater monitoring wells.

2.3 TANK REMOVAL

In March 1992, the UST and ancillary piping were removed from the site (IT, 1993). Soil discoloration, free product on the water table, and odors were noted in the excavation. Soil samples were not collected during the tank removal.

2.4 SITE ASSESSMENT

In August 1998, a Site Assessment was conducted to further evaluate the horizontal and vertical extent of hydrocarbons in the soil and groundwater (Brown and Caldwell, 1999). Twenty-six soil borings (B1 to B26) were drilled and sampled to a maximum depth of approximately 50 feet bgs. Four of the soil borings were converted to groundwater monitoring wells (MW1 to MW4). Locations of the soil borings and groundwater monitoring wells are shown on Figure 2-2.

Soil samples were analyzed for total petroleum hydrocarbons quantified as gasoline (TPH-g), TPH-d, BTEX, and polynuclear aromatic hydrocarbons (PAHs). Laboratory results showed that TPH-d was detected in 14 of the borings, and BTEX was detected in boring B1, located in the former tank cavity, and in boring B4, located approximately 30 feet southeast of the former tank cavity. The most contaminated boring was B1, located in the former tank cavity, which had TPH-d contamination down to 35 feet bgs at levels up to 27,471 milligrams per kilogram (mg/kg) (at 15 feet bgs). TPH-d contamination in boring B1 extended approximately 7 feet below the water table up to a maximum of 15,327 mg/kg. In addition, naphthalene and phenanthrene, both PAHs, were detected in boring B1, and phenanthrene was detected in boring B4. TPH-g was not detected in any of the samples (Brown and Caldwell, 1999). TPH-g and TPH-d results are shown on Figure 2-2, and all other soil sample results are summarized on Table 2-1.

During the site assessment, 34 HydroPunch[®], temporary well, and monitoring well groundwater samples were collected and analyzed for various organic constituents. TPH-d, ethylbenzene, xylenes, and various PAHs were detected in groundwater. The highest concentration of TPH-d detected in groundwater was 640 milligrams per liter (mg/L) in boring B7, located approximately 50 feet downgradient from the former UST (Brown and Caldwell, 1999). A hydrocarbon sheen was reported in B1, located within the tank cavity, and a groundwater contaminant plume was shown to extend approximately 550 feet downgradient of the tank cavity. Groundwater sample results are shown on Figure 2-3, and summarized on Table 2-2.

Overall, results from the site assessment indicated that diesel had migrated from the former tank downward to depths between approximately 25 to 35 feet bgs, where, upon encountering a relatively low-permeability soil layer, migrated laterally downgradient from the tank cavity approximately 550 feet to the south. The data suggest that after the diesel contamination migrated laterally, the groundwater table rose to levels above the low-permeability layer. Groundwater samples subsequently collected during the site assessment from approximately 17 feet bgs contained TPH-d, VOCs, and PAHs, suggesting the contaminants that migrated laterally along the less permeable layer were mobilized with the rising water table (Brown and Caldwell, 1999). Figure 2-4 is a cross section showing the location of impacted soil, the low-permeability layer, and groundwater levels during the 1998 site assessment.

2.5 ADDITIONAL WELL INSTALLATION

In November 2000, four additional groundwater monitoring wells were installed at the site to enhance the groundwater monitoring well network [Foster Wheeler Environmental Corporation (FWENC), 2001a]. One well, MW5, was installed adjacent to the former tank cavity where the highest levels of soil contamination were previously reported. Monitoring wells MW6, MW7, and MW8 were installed to the south-southeast, downgradient of the former tank cavity. Locations of the additional monitoring wells are included on Figure 2-5.

As part of the well installation activities, soil samples were collected from MW5, located adjacent to the former tank cavity, and analyzed for both geotechnical and biological parameters for evaluation of potential *in situ* remedial alternatives. Table 2-3 summarizes physical parameter results, and Table 2-4 summarizes biological parameter results. Results indicate that the soils above the water table have an intrinsic permeability greater than 10^{-10} centimeters squared, which is considered optimal for *in situ* remediation [U.S. Environmental Protection Agency (EPA), 1995] and that the total heterotrophic plate count is greater than 10^{+3} colony forming units per gram, which is also considered optimal for *in situ* remediation (EPA, 1995).

In January 2001, the four new wells were sampled for the first time. Figure 2-5 shows the approximate extent of TPH-d-impacted water above the TPH-d Water Quality Objective (WQO) as extending to the south-southeast approximately 400 feet (FWENC, 2001b). The length of the groundwater contaminant plume was significantly shorter than that reported during the 1998 site investigation (550 feet) (Figure 2-3).

2.6 SOIL EXCAVATION

Between July 26 and July 31, 2001, TPH-d-impacted soil was excavated from the former tank cavity (FWENC, 2001b). Approximately 455 cubic yards of soil were excavated. The horizontal extent of the excavation was approximately 25 feet by 20 feet and the vertical extent of the excavation was 26 feet bgs, except for a small area along the east sidewall where part of the former concrete tank slab had to be left in place at 12 feet bgs due to the presence of nearby underground utilities. The horizontal extent of the excavation was limited due to the presence of nearby underground utilities and Building 43402. The groundwater table was encountered at approximately 26 feet bgs.

Confirmation soil samples were collected from the excavation sidewalls and analyzed for Synthetic Precipitation Leaching Procedure (SPLP)/TPH-d. Analytical results and field instruments indicated that, down to approximately 12 feet bgs, none of the sidewalls were impacted. However, below the former tank pad (approximately 12 feet bgs), leachable TPH-d above the secondary taste and odor WQO for diesel (0.1 mg/L) was present. The range of leachable TPH-d below 12 feet was between 0.22 mg/L (collected at 22 feet bgs along the west sidewall) and 1.6 mg/L (collected at 17 feet bgs along the south sidewall). Results of the confirmation sampling are summarized on Figure 2-6.

In addition to successfully removing a majority of the diesel-impacted soil from the former tank cavity area, approximately 600 pounds of Oxygen Release Compound (ORC[®]) (manufactured by Regenesis Bioremediation Products, Inc.) was added to the top of the saturated zone at approximately 26 feet bgs. Because ORC supplies oxygen to groundwater, its use was intended to enhance natural biological degradation of contaminants present in groundwater beneath the former tank cavity.

The excavation was backfilled to grade with a 2-sack cement per yard of sand slurry conforming to project compaction requirements. The ground surface was subsequently repaved and restored to its original condition.

2.7 GROUNDWATER MONITORING PROGRAM

After the additional groundwater monitoring wells were installed at the site in November 2000 (see Section 2.5), a long-term groundwater monitoring program began. Groundwater samples were collected quarterly from all wells in 2001 (FWENC, 2001a; 2001c; 2001d; 2001e), semiannually in 2002, 2003, and 2004 (FWENC, 2002a; 2002b; 2003) (TtFW, 2003; 2004a; 2004b), and during the first quarter of 2005 (TtFW, 2005a). At the beginning of the monitoring program, all samples were analyzed for TPH-d, BTEX, methyl tert-butyl ether (MTBE), and PAHs. Subsequent samples were analyzed for TPH-d and BTEX, except for the October 2002 event, when samples from wells impacted with TPH-d were again analyzed for PAHs.

Analytical results from the four-year groundwater monitoring program are summarized on Table 2-2, and the results of the most recent groundwater sampling event are shown on Figure 2-7. During the monitoring program, low levels of TPH-d, BTEX, and very low levels of a few PAHs were reported. Overall, the levels of groundwater contamination have decreased with time. Since the beginning of sampling in January 2001, to the most recent event in January 2005, the levels of TPH-d contamination in all impacted wells has decreased. TPH-d in MW5 has decreased from 7.2 mg/L to 0.5 mg/L, in MW7 it has decreased from 1.8 mg/L to 0.2 mg/L, and in MW8 it has decreased from 1.3 mg/L to 0.4 mg/L (Table 2-2).

During the most recent event (January 2005) TPH-d contamination extended downgradient to well MW8 (TPH-d at 0.4 mg/L), located approximately 200 feet from the former tank cavity. Contaminants detected in the well located adjacent to the former tank cavity (MW5) during the January 2005 event included TPH-d at 0.5 mg/L, and BTEX at 0.4 micrograms per liter (µg/L), 0.6 µg/L, 2.0 µg/L, and 3.0 µg/L, respectively.

During the multi-year sampling program, groundwater consistently flowed towards the south with a range of gradients between 0.012 and 0.020 feet per foot. Historical groundwater elevations are included as Table 2-5 and a groundwater elevation contour map from the most recent monitoring event is included as Figure 2-7.

As well as analyzing for contaminants of concern, samples were also analyzed for parameters to evaluate natural attenuation. Laboratory analysis for nitrate and sulfate, along with field measurements of dissolved oxygen (DO) and the oxidation/reduction potential (ORP) were performed. Moreover, iron (II) analyses were performed in the field using a kit specifically designed for this purpose. The historical analytical results and field measurements for the evaluation of natural attenuation parameters are summarized in Table 2-6.

The primary contaminant of concern at the site is TPH-d, which is subject to degradation via biological oxidation. The rate of this process is strongly influenced by the availability of electron acceptors such as DO, nitrate, iron (III), and sulfate.

DO and ORP data, in general, indicate anoxic conditions in monitoring wells containing hydrocarbon constituents (MW5, MW7, and MW8) relative to those which do not contain hydrocarbons (MW1, MW3, and MW6) (Table 2-6). These data suggest that biodegradation is occurring where TPH-d is present which is consuming available oxygen.

Further evidence of oxygen depletion and likely hydrocarbon degradation is observed in decreased nitrate levels and the detection of iron (II) [the product of iron (III) reduction] in samples from wells containing hydrocarbons (MW5, MW7, and MW8) relative to those where hydrocarbons are not detected (Table 2-6). This also suggests that biological oxidation of hydrocarbon constituents is occurring at this site.

Overall, the observed significant decrease in the length of the contaminant plume since sampling began in 1998 (from approximately 550 feet to 200 feet), the overall decreasing levels of contaminants with time (Table 2-2), along with decreased ORP, depletion of DO and nitrate, and the presence of iron (II) in samples from wells where TPH-d is present relative to those wells where TPH-d is not present (Table 2-6), strongly suggest that natural attenuation, including biological oxidation of TPH-d, is occurring at this site.

2.8 BIOVENT PILOT TEST

In September 2003, a biovent pilot test began at Site 43402 to evaluate the feasibility of using bioventing as a potential remediation technology for TPH-d remaining in the vadose zone after the soil excavation. Due to the presence of impacted soils below groundwater, the potential use of biosparging was also tested. A complete summary of the test and test results is included as Appendix A. The primary objectives of the test were to:

- Estimate the bioventing radius of influence
- Evaluate the potential effectiveness of biosparging
- Estimate biological respiration rates in the subsurface via oxygen/carbon dioxide measurement
- Obtain design parameters for potential full-scale implementation
- Evaluate the potential benefit of vapor-phase fertilization of the subsurface to enhance bioventing

The pilot test used two multi-screened wells for air injection (BV-1 and BV-2) and four multi-screened wells for observation (BV-3 through BV-6) specifically installed for the test. Observation wells BV-4 to BV-6 were installed to enhance the monitoring network in April 2004

after the test had progressed for some time. Locations of the wells are shown on Figure 2-8. The injection wells (BV-1 and BV-2) were located near groundwater monitoring well MW5, immediately to the east of the former tank cavity, and the other wells used for observation were located around the injection wells (Figure 2-8). Wells BV-1 to BV-3 consisted of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) casing in a double-nested configuration with screened intervals at approximately 20 and 28 feet bgs. A screen slot size of 0.010 inches was used. In addition, each well contained two ½-inch-diameter Schedule 40 PVC vapor-monitoring probes with screens at approximately 10 feet bgs and 15 feet bgs. Wells BV-4 to BV-6 each consisted of 2-inch-diameter PVC casing in a double-nested configuration with screened intervals at approximately 15 and 20 feet bgs.

The injection wells were connected via aboveground piping to a 5-horsepower positive-displacement blower with 1-inch-diameter carbon steel piping. The test equipment and piping were adequately barricaded and marked to discourage tampering.

To evaluate the potential effectiveness of biosparging, a biosparge test was conducted consisting of simultaneous air injection into wells BV-1 and BV-2 to determine if oxygenation of the surrounding groundwater could be achieved. The amount of groundwater in each well was approximately 2 to 3 feet. Helium gas was bled into the air injection stream for use as a tracer. Monitoring of groundwater DO levels and helium in observation well BV-3, and pressure monitoring and respiratory gas (oxygen and carbon dioxide) monitoring were conducted. The duration of the sparge test was approximately 7 days. The biosparging monitoring data indicated that the groundwater in the vicinity could not be effectively oxygenated. The DO level at MW-5, located approximately 4 feet away from BV-1, did not increase during the test (Appendix A).

A two-part, short-term bioventing test was then conducted. For the first part of the test, air was injected into both BV-1 and BV-2 individually at 5 standard cubic feet per minute (scfm) for several hours to calculate pressure-based radii of influence. For the second part of the test, air was injected at 6 scfm simultaneously into both BV-1 and BV-2 for a 10-day period. During the testing period, oxygen, carbon dioxide, and VOC levels were measured at the other biovent wells and at nearby groundwater monitoring wells. Results indicated that the biovent radii of influence was 42 feet for BV-1 and 38 feet for BV-2 (Appendix A).

After the short-term tests, a 4-month extended bioventing test was conducted. The test parameters were similar to the short-term test – simultaneous injection into BV-1 and BV-2 at 6 scfm; however, air was injected on a pulsed basis. The pulsing scheduling was 7 days of air injection, followed by 4 days of system inactivation. Carbon dioxide production rates and oxygen utilization rates for each pulsing cycle at each well (BV-1, BV-2, BV-3, MW-5) were calculated. Data on the carbon dioxide production showed a general decrease in carbon dioxide production rates with time for all wells monitored. Similarly, data on the oxygen utilization showed a general decrease in oxygen utilization rates with time for all wells monitored.

These trends were interpreted to indicate one of two things:

- Either, carbon dioxide production rates and oxygen utilization rates were decreasing due to declining concentrations of diesel; or
- Carbon dioxide production rates and oxygen utilization rates were decreasing due to declining concentrations of available nutrients, namely, nitrogen.

Stoichiometric calculations suggested that the lack of available nutrients in the subsurface was very likely the primary cause. Therefore, a nutrient addition pilot test was conducted to evaluate the efficiency of adding nutrients to the vadose zone. Nitrogen, essential for cell building, and phosphorus, also necessary for cell building but in lower quantities, were delivered to the vadose zone through gaseous injection of nitrous oxide and triethyl phosphate (TEP) (Appendix A). The nutrients were injected into the vadose zone with the air stream during two 7-day injection, and 4-day off cycles. New wells BV-4, BV-5 and BV-6 were installed immediately prior to the beginning of this test and were used to monitor results. Results indicated that nitrous oxide could be effectively distributed to all monitoring probes (and areas of impacted soil at the former tank cavity), and oxygen and TEP could be effectively delivered to all probes except BV-4, located between the former tank cavity and Building 43402. During drilling of BV-4, the soils encountered contained more clayey material (plastic fines), suggesting they are less permeable. Results of the pilot test indicated that full-scale implementation of bioventing, with nutrient addition, would be successful (Appendix A). However, to effectively biovent the entire area of impacted soil around the former tank cavity, injection would be required in BV-4, as well as BV-1 and BV-2.

2.9 BIOVENT SYSTEM OPERATION

After the pilot test was completed, bioventing began at the site to enhance the bioremediation of TPH-d remaining in the vadose zone around the former tank cavity. Bioventing continued for 12 months, from July 2004 through June 2005. The biovent system previously installed for the pilot test was used, and, based on results from the pilot test, piping was extended to BV-4 so it could be used as an injection well along with BV-1 and BV-2. The addition of nutrients to the subsurface (nitrogen and phosphorus), as tested during the pilot test, was continued. The location of the biovent wells and associated piping is shown in Figure 2-8.

The system was scheduled to operate in a pulsed mode that consisted of 7 days of air and nutrient injection, followed by 7 days of system shutdown. Site visits were conducted weekly to operate and maintain the system.

The operating parameters used during injection were as follows:

- Total air flow into the 3 injection wells: 10 scfm
- Air injection pressure: < 1 pounds per square inch

- Nitrous oxide injection concentration: 500 parts per million. The TEP concentration in the air stream could not be practically measured because no field instruments for detection of TEP are commercially available.

The injection wells and observation wells were scheduled to be measured for oxygen, carbon dioxide, and nitrous oxide weekly, and gas measurements were scheduled to be collected prior to and at the conclusion of each 7-day injection pulse. Nitrous oxide canisters were replaced and the TEP vessel was refilled as necessary. A summary of the data collected during the operation and maintenance of the biovent system is shown in Table 2-7.

Performance of the system was assessed using data collected during the pulse shutdowns. Gas concentration trends during shutdowns can indicate if biological respiration is proceeding. In general, as respiration proceeds and biomass grows, oxygen concentrations will decrease; nitrous oxide concentrations will decrease; and carbon dioxide concentrations will increase.

Gas concentration data collected during pulsed shutdowns showed the following trends:

- At injection well BV-4, oxygen, carbon dioxide, and nitrous oxide concentrations trended as expected; oxygen and nitrous oxide consumption, coupled with carbon dioxide production, was observed. BV-4 was screened in soils containing the highest concentration of TPH-d contamination encountered at the site. Typically, in the most highly diesel-contaminated soils, nitrogen can be rate limiting to biological processes. Therefore, the high utilization of nitrous oxide observed at BV-4 from the start of the operation is expected (see Figure 2-9 for graphical results of the gas data).
- At injection well BV-1, oxygen and carbon dioxide concentrations trended as expected. However, nitrous oxide concentrations showed no appreciable decreases during the shutdowns in the early part of the system operation. Nitrous oxide consumption was, however, observed in the middle part of the system operation. BV-1 was screened in soils containing relatively moderate amounts of TPH-d contamination. It is possible that in the early part of operation, nitrogen demand was not extensive, and naturally occurring nitrogen was sufficient for biomass synthesis, and later, when nitrogen in the soil was tied up or exhausted, nitrous oxide then served as the nitrogen source (see Figure 2-9 for graphical results of the gas data).
- At injection well BV-2, oxygen and carbon dioxide concentrations trended as expected. However, nitrous oxide concentrations did not show any appreciable decrease throughout system operation. BV-2 was screened in soils that contained relatively low levels of TPH-d contamination and, therefore, it is possible that in these soils, naturally occurring nitrogen was present in sufficient quantities to support biomass growth for the duration of operation (see Figure 2-9 for graphical results of the gas data).
- At observation wells MW-5 and BV-3, gas concentrations showed the same basic trends as BV-1. Observation wells MW-5 and BV-3 are located approximately 5 feet and 17 feet, respectively, from injection well BV-1, and thus, the similarity in trends

among these three wells is not considered unusual (see Figure 2-10 for graphical results of the gas data).

In general, the gas concentration data collected during the operation of the biovent system indicated that the system was performing as expected, and biodegradation of TPH-d contamination in the vadose zone was enhanced.

2.10 VERIFICATION SOIL SAMPLING

On July 6, 2005, after the bioventing system had been turned off, verification soil samples were collected from three areas around the former tank cavity that had previously been sampled to compare results and evaluate the effectiveness of bioventing. The verification borings were located immediately adjacent to previous borings, and one sample was collected from each boring at the same depth as previous soil samples in accordance with a site-specific Work Plan (TtFW, 2005b).

After obtaining the appropriate permit, and following utility clearance and Base notification, three verification soil borings (VSB-1, VSB-2, and VSB-3) were advanced with a direct-push rig. The locations of the borings are shown on Figure 2-11. VSB-1 and VSB-2 were located adjacent to biovent injection well BV-4 and biovent observation well BV-6, respectively, and VSB-3 was located adjacent to boring B-4, which was drilled during the 1998 Site Assessment. A copy of the boring permit is included in Appendix C. Following sample collection, each boring was backfilled with a bentonite slurry, and the ground surface was restored to original conditions.

Soil samples were collected from each boring at depths where previous sampling encountered the highest levels of diesel contamination. Samples were collected between 20 and 21 feet bgs in VSB-1, between 22 and 23 feet bgs in VSB-2, and between 19 and 20 feet bgs in VSB-3. Each soil sample was analyzed for TPH-d, SPLP/TPH-d, VOCs (including BTEX, MTBE, and other fuel oxygenates), SPLP/VOCs, PAHs, and SPLP/PAHs. In addition, each sample was also analyzed for hydrocarbon-oxidizing microbial population and general nutrient status (ammonium-nitrogen, nitrate-nitrogen, and orthophosphate as phosphorous).

Results indicated that TPH-d contaminant levels were significantly reduced compared to historical results in each area sampled. A comparison of contaminant results from the July 2005 verification samples and contaminant results from historical sampling at the same location are summarized on Table 2-8 and Figure 2-11, and a comparison of results from recent and historical biological parameter analyses are summarized on Table 2-9. Laboratory analytical reports and chain-of-custody forms are included in Appendix C.

To the north of the former tank cavity TPH-d was reduced from 28,000 mg/kg detected in biovent injection well BV-4 in April 2004, to 3,700 mg/kg in VSB-1 (a reduction of

approximately 87 percent). To the southeast of the former tank cavity TPH-d was reduced from 6,700 mg/kg detected in biovent observation well BV-6 in April 2004, to 760 mg/kg detected in VSB-2 (a reduction of approximately 89 percent). And to the east of the former tank cavity TPH-d was reduced from 8,606 mg/kg detected in Site Assessment boring B-4 in August 1998 (mobile laboratory), to an estimated 12 mg/kg detected in VSB-3 (a reduction of over 99 percent).

Results from the bioparameter analyses on the verification soil samples (hydrocarbon oxidizing microbial population and nutrients) (Table 2-9) are typical for sites that have been biovented with nutrient addition. The data indicate that hydrocarbon-oxidizing microbial populations increased in the soil compared to results from soil samples collected before bioventing began (Table 2-9). In addition, the concentrations of both nitrate-nitrogen as ammonium-nitrogen in soil decreased, indicating biodegradation occurred. However, the orthophosphate-phosphorous concentrations increased in soil during the period of bioventing. Although phosphorus is generally consumed during biodegradation, because only relatively small amounts of phosphorus are required for biomass synthesis (typically, the soil contains sufficient phosphorus), the rate of TEP injection apparently exceeded the rate of phosphate utilization, resulting in increased concentrations of orthophosphate-phosphorus in soil.

Overall, verification soil sampling results indicated that the bioventing and nutrient addition completed from July 2004 to June 2005 around the former tank cavity was very successful in enhancing the biodegradation of TPH-d in the vadose zone.

3.0 ASSESSMENT OF IMPACTS

This section presents information regarding the nature and extent of contamination, site hydrogeology, and an evaluation of potential impacts to nearby resources.

3.1 NATURE AND EXTENT OF CONTAMINATION

Data from previous investigations and remedial activities completed at Site 43402 can be used to delineate the current nature and extent of petroleum hydrocarbons in both soil and groundwater. A description of these impacts is summarized in the following sections.

3.1.1 Soil

Site assessment data (Brown and Caldwell, 1999) identified soil impacted with diesel constituents extending from near the base of the former tank (approximately 12 feet bgs) down to approximately 35 feet bgs, with an approximate 5-foot-thick contaminated layer between approximately 25 to 30 feet bgs extending along a less permeable silt-rich layer to the south approximately 550 feet. Figure 2-4 is Cross Section A to A' from the site assessment report which shows the extent of the impacted soil identified during the 1998 site assessment. Since TPH-d is less dense than water, and the water table was at approximately 17 feet bgs during the 1998 site assessment, the water table must have been significantly lower when the tank originally leaked.

During soil excavation activities completed in 2001, approximately 455 cubic yards of soil were removed from the former tank cavity. The excavation extended vertically to the top of groundwater (26 feet bgs), and was limited horizontally due to nearby underground utilities and Building 43402 (FWENC, 2001b). Laboratory results of confirmation samples indicated TPH-d-impacted soil remained along the sidewalls below approximately 12 feet bgs. To remediate remaining impacted vadose zone soil, bioventing and nutrient addition was performed around the former tank cavity for 12 months between July 2004 and June 2005. Verification soil samples were subsequently collected in July 2005 from areas around the former tank cavity that had previously been sampled to compare results and evaluate the effectiveness of bioventing. Verification soil sample results indicated the bioventing was very successful, reducing TPH-d concentrations in the vadose zone an average of over 90 percent. In the three areas sampled, maximum TPH-d concentrations were reduced from 28,000 mg/kg to 3,700 mg/kg, from 6,700 mg/kg to 760 mg/kg, and from 8,606 mg/kg to an estimated 12 mg/kg.

3.1.2 Groundwater Contamination

Analytical data collected during the most recent groundwater sampling event (January 2005) indicated that TPH-d was present in well MW5, located adjacent to the former tank cavity, at 0.5 mg/L. TPH-d was also present in groundwater in monitoring wells MW7 and MW8, extending downgradient from the former tank cavity up to approximately 200 feet, at 0.2 and 0.4 mg/L,

respectively. BTEX constituents were also detected in groundwater, but in trace to very low levels (Table 2-2, Figure 2-7).

In an effort to evaluate the time required for TPH-d to decrease below its secondary taste and odor WQO of 0.1 mg/L, modeling was completed using the EPA's BIOSCREEN Natural Attenuation Decision Support System model. BIOSCREEN is an analytical model that simulates remediation through natural attenuation of dissolved hydrocarbons at petroleum fuel release sites. Details of the model, the input parameters used, and final results are included as Appendix B. The most current and highest groundwater result for TPH-d at the site (0.5 mg/L, January 2005) was used as the starting concentration input for the model. In addition, site-specific results for hydraulic conductivity, hydraulic gradient, bulk density, and other parameters used to evaluate natural attenuation (DO, nitrate, sulfate, and so forth) were used in the model.

Using BIOSCREEN (Appendix B), and assuming 0.5 mg/L TPH-d is present at the former tank cavity area, results indicated that TPH-d will naturally attenuate to levels below its secondary taste and odor WQO of 0.1 mg/L within approximately 7 years, and not migrate more than 50 feet downgradient of the former tank cavity (Appendix B).

3.2 GEOLOGY AND HYDROGEOLOGY

The geology at the site has been mapped as Quaternary Younger Alluvium overlying the La Jolla Group (Moyle, 1973). The alluvium typically consists of gravel, sand, silt, and clay. The lithologies encountered during subsurface activities at the site consist primarily of poorly and well-graded sand, silty sand, silt, and clay to depths of approximately 50 feet bgs. Boring logs from Site 43402 generally show silt and silty sand extending from the ground surface to approximately 17 feet bgs, a poorly graded sand to silty sand from 17 feet to approximately 26 feet bgs, and a sandy silt to clay below 26 feet bgs.

The site is relatively flat and is predominantly covered by asphalt and concrete. Runoff either percolates into the subsurface in open grass and landscaped areas or flows into nearby storm drains. According to the *Water Quality Control Plan for the San Diego Basin* (RWQCB, 1994), the site is located in the San Juan Hydrologic Unit, which is in the Las Pulgas Hydrologic Subarea of the San Onofre Hydrologic Area. Groundwater within this hydrologic subarea has designated beneficial uses of municipal and agricultural supplies; however, the nearest supply well (10/5 18E2) is located over 3 miles from the site.

Groundwater at the site, as measured during the most recent sampling event completed in January 2005, was encountered between approximately 24 to 26 feet bgs and was flowing to the south with an approximate gradient of 0.02 feet per foot.

3.3 EVALUATION OF POTENTIAL IMPACTS

Groundwater at Camp Pendleton has designated municipal/domestic use. To assess the potential Site 43402 may have to impact groundwater and other nearby resources, the site will be evaluated with criteria related to the effectiveness of the contaminant source removal, site characterization, stability of the groundwater plume, identification of potential nearby sensitive receptors, and whether the site poses a significant risk to human health or the environment. The criteria are presented below, along with applicable information from the site.

1. The leak has been stopped, and ongoing sources have been removed or remediated to the extent practicable.

- The former leaking underground diesel storage tank and the associated piping were removed from the site in 1992 (IT, 1993) (Section 2.3).
- A hydrocarbon sheen was observed on groundwater in the former tank cavity area during site assessment activities completed in 1998 (Brown and Caldwell, 1999) (Section 2.4). However, prior to the multi-year groundwater monitoring program that began in January 2001, four new groundwater monitoring wells were installed, one adjacent to the former tank cavity, and the sheen that was reported on groundwater in 1998 was not observed.
- In 2001, approximately 455 cubic yards of hydrocarbon-impacted soil were excavated from the site (FWENC, 2001b) (Section 2.6). The excavation extended vertically to groundwater, and was limited horizontally due to the presence of underground utilities and Building 43402. Impacted soil was still present along the sidewalls of the excavation below 12 feet.
- To remediate remaining impacted vadose zone soil, bioventing and nutrient addition was performed around the former tank cavity for 12 months between July 2004 and June 2005. After the bioventing, verification soil samples were collected from areas around the former tank cavity that had previously been sampled to compare results and evaluate the effectiveness of the bioventing. Verification soil sample results indicated the bioventing was very successful, reducing TPH-d concentrations in the vadose zone an average of over 90 percent.

2. The site has been adequately characterized.

- A site assessment was completed in 1998. Twenty-six borings were drilled, and soil samples were collected for analysis from each boring (Brown and Caldwell, 1999) (Section 2.4). In addition, groundwater samples were collected from 25 of the borings, and four of the borings were later converted to permanent groundwater monitoring wells.
- Additional Site Characterization activities were completed to determine the lateral extent of hydrocarbon-impacted soil and to install four new groundwater monitoring wells (MW5 to MW8) in order to enhance the monitoring well network (FWENC, 2001a) (Section 2.5).

- Soil excavation activities were completed to remove as much hydrocarbon-impacted soil as practical (FWENC, 2001b) (Section 2.6). The excavation extended vertically to groundwater and horizontally until the excavation could not proceed due to the presence of underground utility lines and Building 43402.
 - A 4-year groundwater monitoring program was completed at the site between 2001 and 2005 (Section 2.7). In 2001 all wells were sampled quarterly, and with semiannual sampling beginning in 2002.
 - Based on the above listed drilling, sampling, and soil excavation activities, it is believed soil and groundwater impacts at the site have been adequately characterized.
3. *The dissolved hydrocarbon plume is not migrating.*
- During the recently completed 4-year groundwater monitoring program (January 2001 to January 2005), relatively low levels of TPH-d were detected in groundwater from wells located up to approximately 200 feet downgradient of the former UST. The maximum level of TPH-d detected during the most recent groundwater sampling event completed in January 2005 was 0.5 mg/L. The contaminant plume has significantly decreased in size since site investigation activities were completed in 1998 (from an estimated 550 feet to an estimated 200 feet) with contaminant levels decreasing overall during the 4-year groundwater monitoring program.
4. *No water wells, deeper drinking water aquifers, surface water, or sensitive receptors are likely to be impacted.*
- Based on the *Marine Corps Base Camp Pendleton Environmental Operations Map* (MCB Camp Pendleton, 2001), the nearest potential sensitive receptor is a riparian habitat that is located approximately ¼ mile to the southeast of the site. This area is not expected to be impacted by Site 43402. Analytical data show the plume is stable/shrinking, and natural attenuation modeling using BIOSCREEN suggests that TPH-d will attenuate to levels below its secondary taste and odor WQO within 7 years and not migrate more than 50 feet downgradient of the former tank cavity.
 - The nearest municipal groundwater supply well, 10/5 18E2, is located over 3 miles to the southwest of Site 43402 and is not expected to be impacted.
 - The nearest surface water body is the Las Flores Creek, located approximately ¼ mile southeast of the site. In addition, a southeasterly flowing tributary to the Las Flores Creek is located toward the northeast, also within ¼ mile of the site (MCB Camp Pendleton, 2001). The surface drainage at the site flows toward the southeast to drainage channels that eventually discharge into the intermittent, southwesterly flowing Las Flores Creek. Because of the relatively low hydraulic gradients across the site, the stable to shrinking nature of the plume, the depth of remaining impacted soil at over approximately 12 feet bgs, and the results of natural attenuation modeling, the potential for nearby surface water bodies to be impacted by Site 43402 is considered insignificant to nonexistent.

5. *The site presents no significant risk to human health.*

- It is extremely unlikely for humans to be exposed to impacted soil because remaining impacted soil is located over approximately 12 feet bgs beneath concrete and asphalt pavement.
- The only potential for human exposure to contaminants in groundwater is through nearby water supply wells. However, the potential for exposure through groundwater is not anticipated due to the long distance to the nearest supply well (over 3 miles) and the stable to shrinking nature of the plume, as indicated during the 4-year groundwater monitoring program (Table 2-2).

6. *The site presents no significant risk to the environment.*

- The site is located approximately ¼ mile from a riparian habitat (MCB Camp Pendleton, 2001). For the same reasons that nearby surface water is not believed to be at risk, it is believed that the environment and nearby ecological receptors are not at risk. The riparian habitat is located relatively far from remaining impacted soil, which is over 12 feet bgs beneath asphalt and concrete pavement.

Based on the above criteria, it is believed that Site 43402 has been adequately characterized and does not present a potential risk to human health or the environment. In summary, the contaminant source (underground storage tank) has been removed, impacted soils have been excavated to the extent practicable, concentrations of remaining impacted vadose zone soil have been reduced by over 90 percent with bioventing, the groundwater plume is stable to shrinking, groundwater contaminant concentrations are decreasing, and nearby sensitive receptors are not expected to be adversely impacted.

4.0 ASSESSMENT OF CLEANUP REQUIREMENTS

Remediation of Site 43402 is monitored by the RWQCB, San Diego Region, which has final review and signature authority for closure. The *San Diego County Site Assessment and Mitigation Manual 2005* (DEH, 2005) provides a framework for investigating and remediating releases of petroleum products; however, cleanup goals are specified in other regulations and guidance. Applicable regulations and guidance for UST sites come from state and federal codes, various resolutions, and guidance documents. The following sections focus on cleanup levels and regulations guiding corrective action for residual contamination.

4.1 APPLICABLE CLEANUP LEVELS

Groundwater cleanup levels for UST Site 43402 are directly related to the RWQCB Basin Plan (RWQCB, 1994). The Basin Plan provides cleanup standards, (WQOs) or Maximum Contaminant Levels (MCLs), for groundwater hydrologic units based on beneficial use designations. A hydrologic unit may be designated for one or more of 23 beneficial uses, such as municipal and domestic supply, agricultural supply, industrial service supply, and so forth. The WQOs for a hydrologic unit must be protective of the most sensitive beneficial use designated for the applicable hydrologic unit. The municipal supply category, which includes sources of drinking water, requires the most protective standards for groundwater.

The RWQCB has designated all groundwater at MCB Camp Pendleton located east of Interstate 5 to be current or potential sources of drinking water. Groundwater designated for use “as domestic or municipal supply shall not contain concentrations of chemical constituents in excess of MCLs” nor shall these waters “contain taste and odor producing substances in concentrations which cause nuisance or adversely affect beneficial uses” (RWQCB, 1994). Therefore, groundwater that is considered a potential source of drinking water cannot contain contaminant concentrations in excess of MCLs (or WQOs) and/or taste and odor water quality thresholds. Cleanup goals for soils are established so that impacted soil does not have the potential to leach contaminants into groundwater at levels above the groundwater cleanup goals. Therefore, as summarized in Table 4-1 and based on the above requirements, the groundwater and soil cleanup goals for typical diesel fuel constituents are directly related to WQOs and MCLs.

4.2 CORRECTIVE ACTION

In addition to regulatory requirements on cleanup levels, California regulations specify corrective action requirements for restoring sites to appropriate cleanup levels. In particular, California State Water Resources Control Board Resolution No. 92-49 (as amended on April 21, 1994 and October 2, 1996) provides policies and procedures for corrective action of unauthorized discharges under Water Code Section 13304. This resolution directs that water affected by an unauthorized release attain either background water quality or the best water

quality that is reasonable if background water quality cannot be restored; however, it does not require that the requisite level of water quality be met at the time of site closure. Also, according to Resolution 92-49, site cleanup must be “consistent with the maximum benefit to the people of state” considering “all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible.” Therefore, corrective action should be reasonable and cost effective with respect to the site-specific conditions.

In Section 5.0, remedial alternatives for UST Site 43402 are identified and evaluated in terms of effectiveness, implementability, and cost.

5.0 IDENTIFICATION AND EVALUATION OF REMEDIAL ALTERNATIVES

This section presents the screening and evaluation process for identifying appropriate remedial alternatives for UST Site 43402. Remedial alternatives screened and evaluated in this CAP are directed at both soil and groundwater. A range of remedial technologies are identified and screened in Section 5.1 in order to select technologies that are expected to be effective, implementable, and cost-effective based on site-specific conditions. Technologies that are not appropriate for the site are eliminated early to streamline the technology evaluation process.

5.1 REMEDIAL TECHNOLOGY SCREENING

The RWQCB requires that a minimum of two corrective action strategies be evaluated. To identify the two most appropriate potential technologies for both soil and groundwater, a variety of remedial options were initially screened. A summary of the screening process for soils is included in Table 5-1, and for groundwater it is included on Table 5-2. The purpose of this screening is to identify and eliminate from further consideration remedial technologies that, because of site-specific conditions or costs, are not the most feasible and/or practical. Based on the screening (see Tables 5-1 and 5-2), the remedial action technologies determined to be the most practical for soil and groundwater at UST Site 43402 are as follows:

Soil:

- Alternative 1: No Further Action
- Alternative 2: Excavation with Off-site Disposal

Groundwater:

- Alternative 1: No Further Action
- Alternative 2: Remediation by Monitored Natural Attenuation

The following sections describe each above identified alternative and include evaluations of effectiveness, implementability, and cost. The evaluation of effectiveness includes consideration of overall protection of human health and the environment and both the long-term and short-term effectiveness of each alternative. Evaluation of the implementability of each alternative includes consideration of the technical and administrative feasibility. The cost evaluation of each alternative is based upon estimates for capital costs and, if applicable, long-term monitoring costs. RWQCB acceptance of the CAP requires that the responsible party address the RWQCB's comments and concerns for each alternative. The RWQCB's acceptance may also not be completed until the public has had a chance to comment on the CAP and the comments have been addressed.

5.2 REMEDIAL ALTERNATIVES FOR SOIL

The following sections describe the two most applicable remedial alternatives, as determined during the alternative screening (Table 5-1), for impacted soil at Site 43402.

5.2.1 Alternative 1: No Further Action

The soil excavation previously completed at the site extended to the groundwater table at approximately 26 feet bgs and removed approximately 455 cubic yards of diesel-impacted soil in the vadose zone (Section 2.6). The excavation did not extend to impacted soils located below the groundwater table, and was not able to remove impacted soils located immediately adjacent to the former tank cavity due to numerous underground utilities and Building 43402.

A biovent pilot test was completed that indicated oxygen and nutrients could effectively be injected into the vadose zone to enhance existing microorganisms ability to biodegrade remaining contamination. A full-scale biovent system was subsequently installed adjacent to the former tank cavity to enhance remediation of the vadose zone soils that could not be excavated (Section 2.9). The biovent system was operated for 12 months and soil confirmation samples indicated the TPH-d levels were reduced by over 90 percent (Section 2.10).

In addition to hydrocarbon contamination remaining in the vadose zone around the former tank cavity, site assessment data collected in 1998 indicate that soil located beneath the water table was also impacted with hydrocarbons.

Under the No Further Action alternative, even though impacted soil is present on site, no additional remediation is proposed. This is based on groundwater data that indicate the remaining impacted soil, located both in the vadose zone and in the saturated zone, are not a significant source of contamination, and human health and nearby sensitive receptors are not anticipated to be adversely impacted.

Data collected from four years of groundwater monitoring (January 2001 to January 2005) have shown that the groundwater contaminant plume is stable and/or shrinking, the concentrations of contaminants are decreasing (Table 2-2), and there is strong evidence that natural attenuation, with biodegradation as the main mechanism, is occurring [strong correlation of decreased ORP, decreased DO, decreased nitrate, and the presence of iron (II) in samples from wells where TPH-d is present relative to those wells where TPH-d is not present (Table 2-6)]. It is presumed in this alternative that natural attenuation will continue to remediate the remaining hydrocarbons present in soil in both the vadose zone and the saturated zone.

The No Further Action alternative is consistent with RWQCB guidance not requiring active remediation for sites where there is evidence that natural attenuation is occurring, where the groundwater plume is not migrating, and where sensitive receptors have been identified and are

not anticipated to be adversely impacted (RWQCB, 1996). The No Further Action alternative, therefore, warrants site closure under existing conditions.

5.2.1.1 Effectiveness

The No Further Action alternative is expected to provide for permanent long-term reduction of remaining hydrocarbon contamination in soil at Site 43402. This would be effective in consideration of the following:

- The source of contamination, the leaking UST and associated piping, has been removed.
- Soil excavation removed a majority of diesel-impacted soils at the former tank cavity down to the groundwater at approximately 26 feet bgs (455 cubic yards). The excavation was limited horizontally due to the presence of underground utilities and Building 43402. Impacted soil remained along the sidewalls of the excavation below 12 feet.
- To remediate remaining impacted vadose zone soil, bioventing and nutrient addition was performed around the former tank cavity for 12 months between July 2004 and June 2005. After bioventing, verification soil samples were collected from areas around the former tank cavity that had previously been sampled to compare results and evaluate the effectiveness of the bioventing. Verification soil sample results indicated the bioventing was very successful, reducing TPH-d concentrations in the vadose zone an average of over 90 percent.
- Soil contamination reported below the water table during the 1998 site assessment has not impacted groundwater to any significant extent. The groundwater plume has decreased in length from approximately 550 feet in 1998, to 400 feet during the beginning of the multi-year groundwater sampling program in 2001, and to approximately 200 feet during the most recent sampling event completed in January 2005. In addition, during the 4-year groundwater monitoring program TPH-d concentrations have decreased in all wells. TPH-d in MW5 decreased from 7.2 mg/L to 0.5 mg/L, in MW7 it decreased from 1.8 mg/L to 0.2 mg/L, and in MW8 it decreased from 1.3 mg/L to 0.4 mg/L (Table 2-2).
- Groundwater data from the four-year monitoring program strongly indicate that natural attenuation, with biodegradation as the main mechanism, is occurring [strong correlation of decreased ORP, decreased DO, decreased nitrate, and the presence of iron (II) in samples from wells where TPH-d is present relative to those wells where TPH-d is not present (Table 2-6)].
- Both a saturated zone soil sample and a vadose zone soil sample analyzed for biological parameters contained sufficient biomass (total heterotrophic plate count of 1.48E^{+07} and 2.25E^{+05} colony forming units, respectively) capable of degrading diesel constituents (Table 2-4). These results are above the number considered optimal by EPA (EPA, 1995).
- Using BIOSCREEN (Appendix B) to model natural attenuation, and assuming 0.5 mg/L TPH-d is present at the former tank cavity area (most recent maximum

concentration in groundwater), results indicated that TPH-d will attenuate to levels below its secondary taste and odor WQO within approximately 7 years, and not migrate more than 50 feet downgradient of the former tank cavity.

- Based on the distance to the nearest municipal supply well (over 3 miles), the long-term stable to shrinking nature of the groundwater plume, the long-term decrease in contaminant levels in groundwater, and the distance to the nearest sensitive ecological receptor (riparian habitat approximately ¼ mile to the southwest), the likelihood of diesel contamination from this site impacting human or sensitive ecological receptors is considered extremely small to negligible.

Considering current site conditions, the No Further Action alternative is considered an effective alternative that is protective of human health and the environment.

5.2.1.2 Implementability

The No Further Action alternative is easy to implement because no further remediation activities would be conducted at UST Site 43402. After regulatory approval for closure, the only activity required would be the proper destruction of the six groundwater monitoring wells at the site.

5.2.1.3 Cost

The only costs associated with the No Further Action alternative would be to properly destroy and document the destruction of the existing groundwater monitoring wells. The estimated cost for the No Further Action alternative is \$15,885. A summary of estimated costs is presented below:

<u>Task</u>	<u>Estimated Cost</u>
Well destruction permits (six wells)	\$785
Drilling subcontractor (\$900 x 6 wells)	\$5,400
Labor for subcontractor coordination and oversight	\$3,000
Transport and dispose of well abandonment debris and soil cuttings	\$3,200
Well destruction documentation	<u>\$3,500</u>
Total Estimated Cost:	<u>\$15,885</u>

5.2.2 Alternative 2: Excavation with Off-site Disposal

Excavation with Off-site Disposal includes removing the remaining TPH-d-impacted soils from both the vadose zone and the saturated zone beneath, around, and downgradient from the former tank cavity area. For this alternative, it is estimated that an area approximately 90 feet by 40 feet will require excavation to between 20 feet bgs and 35 feet bgs. Based on 1998 Environmental Site Assessment results (Brown and Caldwell, 1999), soil reported to contain more than 1,000 mg/kg of TPH-d extended to soil boring B6, located approximately 60 feet from the

downgradient edge of the former tank cavity (see Figure 2-2). Contamination was reported to approximately 20 feet bgs to the southwest of the former tank cavity, and to approximately 35 feet bgs to the southeast of the former tank cavity. Soil excavation activities will only extend to the depth required to remove impacted soils.

Impacted soils around and downgradient of the former tank cavity are located between approximately 15 and 35 feet bgs. All clean overburden encountered will be stockpiled separately and, after analytical testing, will be reused as backfill if appropriate. Not counting clean overburden that must be excavated (90 feet x 40 feet x approximately 15 feet deep = estimated 2000 cubic yards), the volume of impacted soil remaining in both the vadose zone and the saturated zone is estimated to be approximately 1,200 cubic yards.

Before the excavation would begin, the numerous underground utilities, including water, gas, electric, and sewer lines located near the former tank cavity would need to be exposed and rerouted. Due to the proximity of Building 43402, shoring would also be required to protect the building from the excavation. The excavation would proceed until the presence of hydrocarbon contamination was no longer present and confirmation samples indicated that soil cleanup levels were met. The excavation would then be backfilled and the utilities placed back into their original configuration.

5.2.2.1 Effectiveness

For soils, excavation and off-site disposal is a very effective alternative as it protects human health and the environment by removing the contamination and transferring it to an appropriately permitted facility. Excavation provides a permanent removal of the impacted soils.

5.2.2.2 Implementability

Excavation is a well-established, conventional technology for remediating contaminated soil; however, excavation of the current remaining impacted soils at Site 43402 is considered very difficult due to the presence of numerous underground utilities, the proximity of Building 43402, the overall depth of the excavation to (over 3 stories deep), the presence of groundwater at approximately 25 feet bgs suggesting dewatering will likely be required, and the presence of concrete slurry backfill from the previous excavation to 26 feet bgs. Unlike the previous excavation, the numerous gas, electric, water, and sewer utilities located around the former tank cavity would have to be shut off and either temporarily or permanently rerouted before the excavation could proceed. In addition, in order to protect Building 43402 from nearby excavation activities, extensive and deep shoring would be required.

Implementing a relatively deep excavation (35 feet) around utilities and a building also presents potential risks to workers from physical hazards, as well as potential contact with contaminated

soil. These risks, however, can be minimized by preparing a detailed site-specific work plan and a detailed site-specific health and safety plan.

5.2.2.3 Cost

The following assumptions were made to develop a cost estimate for the excavation with off-site disposal alternative:

- An estimated 2,000 cubic yards of clean overburden and 1,200 cubic yards of diesel-impacted soil would be excavated. The impacted soils would be transported off site for disposal as a non-hazardous waste.
- The numerous underground utilities around the former tank cavity would need to be either temporarily rerouted or supported prior to the excavation.
- Extensive shoring would be required along approximately 40 linear feet of Building 43402 to protect it from the excavation.

The total estimated cost for the Excavation with Off-site Disposal alternative is approximately \$417,000. A general breakdown of the estimated costs is included below:

<u>Task</u>	<u>Estimated Cost</u>
Remedial Action Work Plan (draft and final versions)	\$15,000
Utility rerouting/supporting (\$15,000) and shoring (\$50,000)	\$65,000
Soil excavation, backfill, and site restoration (approximately 1,200 cubic yards impacted soil and approximately 2,000 cubic yards of clean overburden) (estimated \$55/yard)	\$176,000
Confirmation soil sample analyses [25 x \$90 (TPH-d) + 25 x \$180 (VOCs) + 15 x \$176 (PAHs)]	\$9,390
Transport and dispose of contaminated soil (1,200 cubic yards = 1,800 tons) (\$45/ton)	\$81,000
Site supervision (5 weeks construction supervisor at \$110/hour and other support at \$85/hour)	\$48,750
Site Closure Report (draft and final versions)	\$22,000
Total Estimated Cost:	<u>\$417,140</u>

5.3 REMEDIAL ALTERNATIVES FOR GROUNDWATER

The following sections describe the two most applicable remedial alternatives, as determined during the alternative screening (Table 5-2), for impacted groundwater at Site 43402.

5.3.1 Groundwater Alternative 1: No Further Action

Under the No Further Action alternative, no groundwater remediation is proposed for the site. It is, however, presumed that 1) the relatively low levels of TPH-d currently present in

groundwater (maximum 0.5 mg/L, January 2005) will continue to be remediated via natural processes, and 2) nearby sensitive receptors have been identified and are not anticipated to be adversely impacted.

Data collected from the four-year groundwater monitoring program completed between 2001 and 2005 have shown a decrease in the length of the contaminant plume; decreasing levels of TPH-d in each well (Table 2-2); and strong evidence of natural attenuation via biodegradation [decreased ORP, decreased DO, decreased nitrate, and the presence of iron (II) in samples from wells where TPH-d is present relative to those wells where TPH-d is not present (Table 2-6)]; which all strongly suggest that natural attenuation (primarily biological oxidation) of TPH-d is occurring at this site.

It is therefore believed that the minor amounts of diesel components currently present in groundwater (up to 0.5 mg/L of TPH-d) will continue to degrade naturally over time. It is implicit in this alternative that, based on the fact that contamination levels are low, there is evidence that natural attenuation is occurring, and the only contaminants of interest at the site are constituents of diesel, the expense associated with active remediation would be an unnecessary use of public resources.

5.3.1.1 Effectiveness

The No Further Action alternative for groundwater would be effective in providing protection of human health and the environment in consideration of the following:

- The source of contamination, the leaking UST and associated piping, has been removed.
- Soil excavation removed a majority of diesel-impacted soils at the former tank cavity down to the groundwater at approximately 26 feet bgs (455 cubic yards). The excavation was limited horizontally due to the presence of underground utilities and Building 43402. Impacted soil remained along the sidewalls of the excavation below 12 feet.
- To remediate remaining impacted vadose zone soil, bioventing and nutrient addition was performed around the former tank cavity for 12 months between July 2004 and June 2005. After bioventing, verification soil samples were collected from areas around the former tank cavity that had previously been sampled to compare results and evaluate the effectiveness of the bioventing. Verification soil sample results indicated the bioventing was very successful, reducing TPH-d concentrations in the vadose zone an average of over 90 percent.
- Soil contamination reported below the water table during the 1998 environmental site assessment has not impacted groundwater to any significant extent. The groundwater plume has decreased in length from approximately 550 feet in 1998, to 400 feet in 2001, and to approximately 200 feet during the most recent sampling event completed in January 2005. In addition, during the 4-year groundwater monitoring program TPH-d concentrations have decreased in all wells. TPH-d in MW5 decreased from

7.2 mg/L to 0.5 mg/L, in MW7 it decreased from 1.8 mg/L to 0.2 mg/L, and in MW8 it decreased from 1.3 mg/L to 0.4 mg/L (Table 2-2).

- Groundwater data from the four-year monitoring program strongly indicate that natural attenuation, with biodegradation as the main mechanism, is occurring [strong correlation of decreased ORP, decreased DO, decreased nitrate, and the presence of iron (II) in samples from wells where TPH-d is present relative to those wells where TPH-d is not present (Table 2-6)].
- Both a saturated zone soil sample and a vadose zone soil sample analyzed for biological parameters contained sufficient biomass (total heterotrophic plate count of $1.48E^{+07}$ and $2.25E^{+05}$ colony forming units, respectively) capable of degrading diesel constituents (Table 2-4). These results are above the number considered optimal by EPA (EPA, 1995).
- Using BIOSCREEN (Appendix B) to model natural attenuation, and assuming 0.5 mg/L TPH-d is present at the former tank cavity area (most recent maximum concentration in groundwater), results indicated that TPH-d will attenuate to levels below its secondary taste and odor WQO within approximately 7 years, and not migrate more than 50 feet downgradient of the former tank cavity.
- Based on the distance to the nearest municipal supply well (over 3 miles), the long-term stable to shrinking nature of the groundwater plume, the long-term decrease in contaminant levels in groundwater, the depth of current remaining soil contamination (between approximately 12 and 26 feet), and the distance to the nearest sensitive ecological receptor (riparian habitat approximately ¼ mile to the southwest), the likelihood of diesel contamination from this site impacting human or sensitive ecological receptors is considered extremely small to negligible.

Considering site conditions, the No Further Action alternative for groundwater is considered an effective alternative that is protective of human health and the environment.

5.3.1.2 Implementability

The No Further Action alternative for groundwater is very easy to implement, as no groundwater remediation or monitoring activities would be conducted. After regulatory approval for closure, the groundwater monitoring wells at the site would be properly destroyed.

5.3.1.3 Cost

The only costs associated with the No Further Action alternative would be to properly destroy and document the destruction of the existing groundwater monitoring wells. The estimated cost is for the No Further Action alternative is \$15,885. A summary of estimated costs is presented below:

<u>Task</u>	<u>Estimated Cost</u>
Well destruction permits (six wells)	\$785
Drilling subcontractor (\$900 x 6 wells)	\$5,400
Labor for subcontractor coordination and oversight	\$3,000
Transport and dispose of well abandonment debris and soil cuttings	\$3,200
Well destruction documentation	<u>\$3,500</u>
Total Estimated Cost:	<u>\$15,885</u>

5.3.2 Alternative 2: Remediation by Monitored Natural Attenuation

Alternative 2 relies on natural attenuation mechanisms for the remediation of residual groundwater contamination, and for this alternative, it is proposed that monitored natural attenuation (MNA) would require periodic groundwater monitoring to verify that natural attenuation processes were continuing to occur and that contaminant concentrations were continuing to decrease. With regard to groundwater, natural attenuation is generally defined as a process by which contaminants are degraded, or reduced in concentration, by various naturally occurring processes. Major natural attenuation processes include biodegradation, dispersion, dilution, volatilization, and adsorption. The MNA alternative for groundwater is expected to provide for permanent, long-term reduction of contaminants.

5.3.2.1 Effectiveness

For groundwater, natural attenuation via biodegradation is generally considered effective for petroleum hydrocarbons at low levels (EPA, 1995). Biodegradation of petroleum hydrocarbons occurs most efficiently under aerobic conditions. As biodegradation occurs, oxygen is consumed, which is replenished by diffusion through soil pore-space over a concentration gradient.

For groundwater, MNA is expected to effectively provide for protection of human health and the environment for the same reasons as described above for the No Further Action alternative. Those reasons are reiterated here:

- The source of contamination, the leaking UST and associated piping, has been removed.
- Soil excavation removed a majority of diesel-impacted soils at the former tank cavity down to the groundwater at approximately 26 feet bgs (455 cubic yards). The excavation was limited horizontally due to the presence of underground utilities and Building 43402. Impacted soil remained along the sidewalls of the excavation below 12 feet.
- To remediate remaining impacted vadose zone soil, bioventing and nutrient addition was performed around the former tank cavity for 12 months between July 2004 and June 2005. After bioventing, verification soil samples were collected from areas

around the former tank cavity that had previously been sampled to compare results and evaluate the effectiveness of the bioventing. Verification soil sample results indicated the bioventing was very successful, reducing TPH-d concentrations in the vadose zone an average of over 90 percent.

- Soil contamination reported below the water table during the 1998 site assessment has not impacted groundwater to any significant extent. The groundwater plume has decreased in length from approximately 550 feet in 1998, to 400 feet in 2001, and to approximately 200 feet during the most recent sampling event completed in January 2005. In addition, during the 4-year groundwater monitoring program TPH-d concentrations have decreased in all wells. TPH-d in MW5 decreased from 7.2 mg/L to 0.5 mg/L, in MW7 it decreased from 1.8 mg/L to 0.2 mg/L, and in MW8 it decreased from 1.3 mg/L to 0.4 mg/L (Table 2-2).
- Groundwater data from the four-year monitoring program strongly indicate that natural attenuation, with biodegradation as the main mechanism, is occurring [strong correlation of decreased ORP, decreased DO, decreased nitrate, and the presence of iron (II) in samples from wells where TPH-d is present relative to those wells where TPH-d is not present (Table 2-6)].
- Both a saturated zone soil sample and a vadose zone soil sample analyzed for biological parameters contained sufficient biomass (total heterotrophic plate count of 1.48E^{+07} and 2.25E^{+05} colony forming units, respectively) capable of degrading diesel constituents (Table 2-4). These results are above the number considered optimal by EPA (EPA, 1995).
- Using BIOSCREEN (Appendix B) to model natural attenuation, and assuming 0.5 mg/L TPH-d is present at the former tank cavity area (most recent maximum concentration in groundwater), results indicated that TPH-d will attenuate to levels below its secondary taste and odor WQO within approximately 7 years, and not migrate more than 50 feet downgradient of the former tank cavity.
- Based on the distance to the nearest municipal supply well (over 3 miles), the long-term stable to shrinking nature of the groundwater plume, the long-term decrease in contaminant levels in groundwater, the depth of current remaining soil contamination (between approximately 12 and 26 feet), and the distance to the nearest sensitive ecological receptor (riparian habitat approximately ¼ mile to the southwest), the likelihood of diesel contamination from this site impacting human or sensitive ecological receptors is considered extremely small to negligible.

In consideration of these points, the MNA for groundwater alternative is considered an effective remedial alternative for this site.

5.3.2.2 Implementability

MNA is moderately easy to implement, as no active remediation activities would be conducted. Implementation of MNA would consist of collecting groundwater samples from existing monitoring wells over time to assess contaminant concentrations and biological activity.

5.3.2.3 Cost

The following assumptions were made to develop a cost estimate for the MNA alternative for groundwater:

- Three years of semiannual groundwater monitoring would be required to confirm that levels of groundwater contamination are continuing to decrease.
- Fate and transport modeling will not be required to predict contaminant reduction and/or migration, nor would a contingency plan be required to address the possibility that contaminant reduction will not occur as estimated, because: 1) contaminants are currently present at low concentrations, 2) the groundwater plume has been shown to be stable and shrinking, and 3) impacts to human or sensitive ecological receptors are not expected.

The total cost associated with the MNA alternative for groundwater (including properly abandoning and documenting the destruction of the existing groundwater monitoring wells at closure) is approximately \$81,105. A general breakdown of the estimated costs is included below:

<u>Task</u>	<u>Estimated Cost</u>
Semiannual groundwater sampling field labor for 3 years (6 events x 2 persons x 16 hrs/event x \$85/hr)	\$16,320
Groundwater sample analysis (6 samples TPH-d (\$90)/event + 7 samples VOCs (\$180)/event x 6 events)	\$10,800
Transport and dispose well purge water (6 events)	\$5,100
Semiannual Groundwater Sampling Reports (\$5,500/report x 6 reports)	\$33,000
Well destruction and documentation (see Section 5.3.1.3)	<u>\$15,885</u>
Total Estimated Cost:	<u>\$81,105</u>

6.0 RECOMMENDATIONS

The No Further Action alternative for both soils and groundwater are the requested alternatives for UST Site 43402. This request is supported based on the following:

- **Source Removal.** In 1992, the UST and associated piping were removed from the site. In 2001, approximately 455 cubic yards of TPH-d-impacted soil was excavated; however, the excavation was limited horizontally due to the presence of numerous underground utilities and Building 43402, and did not extend below groundwater. Even though impacted soil is present in the vadose zone around the former tank cavity, and in the saturated zone beneath and near the former tank cavity, data from four years of groundwater monitoring indicate this soil is not a contaminant source of concern, as the groundwater plume has shrunk/remained stable, TPH-d concentrations have decreased, and there is very strong evidence that natural attenuation (primarily biodegradation) is actively occurring at the site.
- **Extent of Contamination.** 1998 Environmental Site Assessment data identified soil impacted with diesel constituents extending from near the base of the former tank (approximately 12 feet bgs) down to approximately 35 feet bgs (the top of groundwater is currently approximately 25 feet bgs). Soil excavation activities removed approximately 455 cubic yards of impacted soil down to groundwater, however the excavation was limited horizontally. Based on results of confirmation samples, TPH-d-impacted soils remained along the sides of the excavation. Bioventing, completed for 12 months between July 2004 and June 2005, subsequently reduced remaining vadose zone contamination by over 90 percent. Since the excavation did not extend below groundwater, the TPH-d impacted soils reported during the 1998 environmental site assessment below groundwater around and downgradient of the former tank cavity (up to 35 feet bgs) were not excavated.

Analytical data collected during the most recent groundwater sampling event (January 2005) indicated that TPH-d was present in well MW5, located adjacent to the former tank cavity, at 0.5 mg/L. TPH-d was also present in groundwater in monitoring wells MW7 and MW8, extending downgradient from the former tank cavity up to approximately 200 feet, at levels up to 0.4 mg/L. BTEX constituents were also detected in groundwater, but in trace to very low levels. BTEX was not detected above MCLs.

- **Plume Stability.** During the 4-year groundwater monitoring program completed between January 2001 and January 2005, TPH-d levels have been shown to be low (up to 0.5 mg/L TPH-d in January 2005) with an overall history of decreasing in all wells where it is present (TPH-d in MW5 decreased from 7.2 mg/L to 0.5 mg/L, in MW7 it decreased from 1.8 mg/L to 0.2 mg/L, and in MW8 it decreased from 1.3 mg/L to 0.4 mg/L). Overall, the groundwater plume has decreased in length from approximately 550 feet during the site assessment in completed in 1998, to 400 feet in 2001, to approximately 200 feet during the most recent sampling event.
- **Risk.** Based on the distance to the nearest municipal supply well (over 3 miles), the distance to the nearest surface water body approximately (¼ mile to the southwest),

the long-term shrinking to stable nature of the groundwater plume, the long-term decreasing concentrations of TPH-d in groundwater, the depth of current remaining soil contamination (over 12 bgs), the distance to the nearest sensitive ecological receptor (riparian habitat approximately ¼ mile to the southwest), and the strong evidence that natural attenuation is actively occurring at the site, the likelihood of diesel contamination from this site impacting human or sensitive ecological receptors is considered extremely small to negligible.

- **Cost.** The costs for Excavation with Off-Site Disposal for impacted soils that are not considered a contaminant source of concern (\$417,000), and the costs for continued monitoring of natural attenuation (3 additional years for \$81,105) for a groundwater plume that is shrinking/stable, and has decreasing concentration levels, are significant when compared to the cost for No Further Action for both soil and groundwater (\$15,885). Such expenditures for active soil remediation and continued groundwater monitoring on a site that poses no imminent risk to human health or the environment are believed to be an unnecessary use of public resources. Perhaps equally or more importantly, such expenditures would, in light of MCB Camp Pendleton's limited budget for environmental remediation, result in decreased availability of funds for remediation of sites that actually pose risks to human health or the environment.
- **Time Frame.** In an effort to evaluate the time required for TPH-d in groundwater to decrease to a level below its secondary taste and odor water quality objective, natural attenuation modeling was completed using EPA's BIOSCREEN software (Appendix B). During the modeling, the maximum groundwater concentration of TPH-d detected during recent monitoring was used as the starting concentration input for the model (0.5 mg/L). Since diesel fuel consists of a multitude of chemicals, in order to model TPH-d degradation in groundwater, naphthalene, which is a common constituent of diesel, was conservatively selected as a proxy for TPH-d (Appendix B). Model results indicated that TPH-d is estimated to attenuate to levels below its secondary taste and odor WQO during the next 7 years and not migrate more than 50 feet from the former tank cavity. Model results indicate that TPH-d will attenuate to levels below its WQO well before it reaches the nearest drinking water well located over 3 miles downgradient of the site.

In summary, there are no known current pathways for exposure to remaining contaminants, shallow groundwater near Building 43402 is not expected to be used for any purpose in the foreseeable future, and costs for additional deep soil excavation and further groundwater monitoring to continue to observe natural attenuation are relatively significant. Therefore, in consideration of "all demands being made and to be made on these waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible," site closure with No Further Action for both soil and groundwater is requested for UST Site 43402.

7.0 REFERENCES

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TABLES

TABLE 2-1

**SUMMARY OF HISTORICAL SOIL SAMPLING RESULTS
MCB CAMP PENDLETON, UST SITE 43402**

Analysis	Stationary Laboratory Results	
	Sample Numbers	
	43402-B1-15.0	43402-B4-20.0
<i>PAHs</i>	(mg/kg)	(mg/kg)
Acenaphthene	<0.5	<0.1
Acenaphthylene	<0.5	<0.1
Anthracene	<1.0	<0.2
Benzo[a]anthracene	<0.5	<0.1
Benzo[a]pyrene	<0.5	<0.1
Benzo[b]fluoranthene	<2.0	<0.3
Benzo[g,h,i]perylene	<0.5	<0.1
Benzo[k]fluoranthene	<0.5	<0.1
Chrysene	<0.5	<0.1
Dibenzo[a,h]anthracene	<0.5	<0.1
Fluoranthene	<1.0	<0.2
Fluorene	<0.5	<0.1
Indeno[1,2,3-c,d]pyrene	<0.5	<0.1
Naphthalene	18	<0.2
Phenanthrene	18	2.5
Pyrene	<0.5	<0.1

Notes:

EPA - U.S. Environmental Protection Agency

MCB - Marine Corps Base

mg/kg - micrograms per kilogram

PAH - polynuclear aromatic hydrocarbon (EPA Method 8270)

UST - Underground Storage Tank

Source:

Brown and Caldwell, 1999

TABLE 2-2

SUMMARY OF GROUNDWATER SAMPLING RESULTS
UST SITE 43402, MCB CAMP PENDLETON, CA

Well ID	Date Sampled	Sample ID	TPH-d mg/L	VOCs ⁽¹⁾					PAHs ⁽¹⁾					
				Benzene µg/L	Toluene µg/L	Ethylbenzene µg/L	Total Xylenes µg/L	MTBE µg/L	Acenaphthylene µg/L	Fluorene µg/L	Fluoranthene µg/L	Pyrene µg/L	Anthracene µg/L	Chrysene µg/L
Water Quality Objectives (MCLs)			0.1 ⁽²⁾	1	150	680	1750	(3)	(3)	(3)	(3)	(3)	(3)	0.2 ⁽⁴⁾
MW1	26-Aug-98	43402-B25/MW1	--	--	--	--	--	na	na	na	na	na	na	na
	24-Jan-01	0024-073	--	--	--	--	--	--	--	--	--	--	--	--
	20-Apr-01	0024-121	--	--	--	--	--	na	na	na	na	na	na	na
	8-Aug-01	0024-248	--	--	--	--	--	na	na	na	na	na	na	na
	24-Oct-01	0024-314	--	--	--	--	--	na	na	na	na	na	na	na
	26-Apr-02	0024-367	1 ⁽⁵⁾	--	--	--	--	na	na	na	na	na	na	na
	18-Oct-02	0024-443	--	--	--	--	--	na	na	na	na	na	na	na
	21-Apr-03	0024-471	--	--	--	--	--	na	na	na	na	na	na	na
	2-Oct-03	0024-528	--	--	--	--	--	na	na	na	na	na	na	na
	19-Jan-04	0063-045	--	--	--	--	--	na	na	na	na	na	na	na
8-Jul-04	0081-042	--	0.2J	0.1J	--	1J	na	na	na	na	na	na	na	
13-Jan-05	0081-066	--	--	0.2J	--	1J	na	na	na	na	na	na	na	
MW2 ⁽⁶⁾	26-Aug-98	43402-B24/MW2	--	--	--	--	--	na	na	na	na	na	na	na
MW3	26-Aug-98	43402-B26/MW3	--	--	--	--	--	na	na	na	na	na	na	na
	24-Jan-01	0024-071	--	--	--	--	--	--	--	--	--	--	--	--
	19-Apr-01	0024-116	--	--	--	--	--	na	na	na	na	na	na	na
	7-Aug-01	0024-241	--	--	--	--	--	na	na	na	na	na	na	na
	24-Oct-01	0024-312	--	--	--	--	--	na	na	na	na	na	na	na
	25-Apr-02	0024-363	--	--	--	--	--	na	na	na	na	na	na	na
	18-Oct-02	0024-437	--	--	--	--	--	na	na	na	na	na	na	na
	21-Apr-03	0024-472	--	--	--	--	--	na	na	na	na	na	na	na
	1-Oct-03	0024-527	--	--	--	--	--	na	na	na	na	na	na	na
	19-Jan-04	0063-043	--	--	--	--	--	na	na	na	na	na	na	na
	19-Jan-04	0063-044 (Dup)	--	--	--	--	--	na	na	na	na	na	na	na
	7-Jul-04	0081-040	--	0.2J	0.1J	--	1J	na	na	na	na	na	na	na
12-Jan-05	0081-063	--	0.1J	0.2J	--	1J	na	na	na	na	na	na	na	
MW4 ⁽⁶⁾	26-Aug-98	43402-B22/MW4	--	--	--	--	--	na	na	na	na	na	na	na
MW5	24-Jan-01	0024-072	7.2	--	--	0.29J	--	--	--	12J	--	--	5.6J	--
	20-Apr-01	0024-120	1.9	--	--	0.28J	--	na	na	na	na	na	na	na
	8-Aug-01	0024-243	4	--	--	--	--	na	na	na	na	na	na	na
	8-Aug-01	0024-244 (Dup)	3.4	--	--	--	--	na	na	na	na	na	na	na
	24-Oct-01	0024-308	2.4	--	--	0.41J	--	na	na	na	na	na	na	na
	24-Oct-01	0024-309 (Dup)	2.4	--	--	0.36J	--	na	na	na	na	na	na	na
	26-Apr-02	0024-366	8.3	--	--	--	--	na	na	na	na	na	na	na
	18-Oct-02	0024-439	3.9	--	--	0.4J	--	na	1.6J	4	1.2	0.3	--	--
	18-Oct-02	0024-440 (Dup)	6.1	--	--	0.56	--	na	1.5J	3.8	1.1	0.2	--	--
	22-Apr-03	0024-477	1	0.37	--	1.3	--	na	na	na	na	na	na	na
	22-Apr-03	0024-478 (Dup)	1	.4J	--	1.4	--	na	na	na	na	na	na	na
	1-Oct-03	0024-527	--	--	--	--	--	na	na	na	na	na	na	na
	20-Jan-04	0063-048	1.2	--	--	0.82	--	na	na	na	na	na	na	na
	8-Jul-04	0081-046	0.7	0.3J	0.2J	2	0.9J	na	na	na	na	na	na	na
	13-Jan-05	0081-069	0.5	0.2J	0.2J	1	0.8J	na	na	na	na	na	na	na
13-Jan-05	0081-070 (Dup)	0.5	0.4J	0.6	2	3	na	na	na	na	na	na	na	

TABLE 2-2

**SUMMARY OF GROUNDWATER SAMPLING RESULTS
UST SITE 43402, MCB CAMP PENDLETON, CA**

Well ID	Date Sampled	Sample ID	TPH-d mg/L	VOCs ⁽¹⁾					PAHs ⁽¹⁾					
				Benzene µg/L	Toluene µg/L	Ethylbenzene µg/L	Total Xylenes µg/L	MTBE µg/L	Acenaphthylene µg/L	Fluorene µg/L	Fluoranthene µg/L	Pyrene µg/L	Anthracene µg/L	Chrysene µg/L
Water Quality Objectives (MCLs)			0.1 ⁽²⁾	1	150	680	1750	(3)	(3)	(3)	(3)	(3)	(3)	0.2 ⁽⁴⁾
MW6	25-Jan-01	0024-077	-- ⁽⁷⁾	--	--	--	--	--	--	--	--	--	--	--
	19-Apr-01	0024-115	--	--	--	--	--	na	na	na	na	na	na	na
	7-Aug-01	0024-240	--	--	--	--	--	na	na	na	na	na	na	na
	24-Oct-01	0024-310	--	--	--	--	--	na	na	na	na	na	na	na
	25-Apr-02	0024-364	--	--	--	--	--	na	na	na	na	na	na	na
	18-Oct-02	0024-438	--	--	--	--	--	na	na	na	na	na	na	na
	21-Apr-03	0024-473	--	--	--	--	--	na	na	na	na	na	na	na
	1-Oct-03	0024-526	--	--	--	--	--	na	na	na	na	na	na	na
	19-Jan-04	0063-042	--	--	--	--	--	na	na	na	na	na	na	na
	7-Jul-04	0081-039	--	0.2J	0.2J	--	1J	na	na	na	na	na	na	na
12-Jan-05	0081-064	--	0.08J	0.2J	--	0.6J	na	na	na	na	na	na	na	
MW7	25-Jan-01	0024-079	1.8	--	--	--	--	--	3.7J	3.2J	--	--	--	0.12J
	19-Apr-01	0024-117	0.72	--	--	--	--	na	na	na	na	na	na	na
	19-Apr-01	0024-118 (Dup)	1	--	--	--	--	na	na	na	na	na	na	na
	8-Aug-01	0024-246	1.9	--	--	--	--	na	na	na	na	na	na	na
	24-Oct-01	0024-311	0.63	--	--	--	--	na	na	na	na	na	na	na
	25-Apr-02	0024-360	1.3	--	--	--	--	na	na	na	na	na	na	na
	25-Apr-02	0024-361 (Dup)	1	--	0.24J	--	--	na	na	na	na	na	na	na
	17-Oct-02	0024-436	1.2	--	--	--	--	na	--	1	0.88	--	--	--
	22-Apr-03	0024-476	0.33	--	--	--	--	na	na	na	na	na	na	na
	2-Oct-03	0024-530	0.32	--	--	--	--	na	--	--	--	--	--	--
	2-Oct-03	0024-531 (Dup)	0.31	--	--	--	--	na	na	na	na	na	na	na
	20-Jan-04	0063-047	0.37	--	--	--	--	na	na	na	na	na	na	na
	8-Jul-04	0081-045	0.2	0.1J	0.2J	--	0.9J	na	na	na	na	na	na	na
13-Jan-05	0081-068	0.2	0.09J	0.2J	--	1J	na	na	na	na	na	na	na	
MW8	25-Jan-01	0024-075	1.3	--	--	--	--	--	3.2J	1.6J	--	--	--	--
	25-Jan-01	0024-076 (Dup)	1.2	--	--	--	--	--	4.1J	1.6J	--	--	--	--
	19-Apr-01	0024-119	0.75	--	--	--	--	na	na	na	na	na	na	na
	8-Aug-01	0024-247	0.81	--	--	--	--	na	na	na	na	na	na	na
	24-Oct-01	0024-313	0.62	--	--	--	--	na	na	na	na	na	na	na
	25-Apr-02	0024-362	0.66	--	--	--	--	na	na	na	na	na	na	na
	18-Oct-02	0024-441	1	--	--	--	--	na	--	1.4	0.35J	0.16J	--	--
	22-Apr-03	0024-475	0.4	--	--	--	--	na	na	na	na	na	na	na
	2-Oct-03	0024-529	1.6	--	--	--	--	na	na	na	na	na	na	na
	20-Jan-04	0063-046	1.6	--	--	--	--	na	na	na	na	na	na	na
	8-Jul-04	0081-043	0.5	0.2J	0.1J	--	0.9J	na	na	na	na	na	na	na
	8-Jul-04	0081-044 (Dup)	0.6	0.2J	0.2J	--	0.9J	na	na	na	na	na	na	na
13-Jan-05	0081-067	0.4	0.1J	0.2J	--	1J	na	na	na	na	na	na	na	
Reporting Limits			0.1	0.5	0.5	0.5	1.5	0.5	4	0.4	0.4	0.2	0.2	0.2

TABLE 2-2

**SUMMARY OF GROUNDWATER SAMPLING RESULTS
UST SITE 43402, MCB CAMP PENDLETON, CA**

Well ID	Date Sampled	Sample ID	TPH-d mg/L	VOCs ⁽¹⁾					PAHs ⁽¹⁾					
				Benzene µg/L	Toluene µg/L	Ethylbenzene µg/L	Total Xylenes µg/L	MTBE µg/L	Acenaphthylene µg/L	Fluorene µg/L	Fluoranthene µg/L	Pyrene µg/L	Anthracene µg/L	Chrysene µg/L
Water Quality Objectives (MCLs)			0.1 ⁽²⁾	1	150	680	1750	(3)	(3)	(3)	(3)	(3)	(3)	0.2 ⁽⁴⁾

Notes:

Bold values exceed listed Water Quality Objectives

(1) - Compounds detected above laboratory method detection limits

(2) - Secondary taste and odor objective

(3) - No established Water Quality Objective

(4) - Proposed primary MCL

(5) - Presence of atypical pattern, quantified against diesel calibration curve

(6) - Well abandoned

(7) - Presence of a single peak on chromatogram in the diesel range

-- - not detected above laboratory reporting limit

µg/L - micrograms per liter

Dup - duplicate sample

EPA - U.S. Environmental Protection Agency

J - estimated value; value falls between the method detection limit and project reporting limit

MCB - Marine Corps Base

MCL - Maximum Contaminant Level

mg/L - milligrams per liter

MTBE - methyl tert-butyl ether

na - not analyzed

PAH - polynuclear aromatic hydrocarbon (by EPA Method 8310)

TPH-d - total petroleum hydrocarbons quantified as diesel (by EPA Method 8015B)

UST - Underground Storage Tank

VOC - volatile organic compound (by EPA Method 8260B and BTEX by EPA Method 8021B)

TABLE 2-3

**SUMMARY OF PHYSICAL PARAMETERS FOR SOIL SAMPLES FROM
WELL BORING 43402-B27/MW5, MCB CAMP PENDLETON, JANUARY 20001**

Sample ID	Depth (feet)	Bulk Density (g/cc)	Grain Density (g/cc)	Intrinsic Permeability to Water¹ (millidarcy)	Intrinsic Permeability² (cm²)	Saturated Hydraulic Conductivity (cm/s)	Moisture Content (wt. %)
Optimal Range³		N/A	N/A	N/A	>10⁻¹⁰	na	12-18⁽⁴⁾
0024-050	14.5	1.76	2.66	0.41	4.05E-12	3.97E-07	19.4
0024-051	22	1.66	2.76	621	6.00E-09	5.88E-04	4.8
0024-035	28	1.71	na	0.36	3.54E-12	3.47E-07	24.8

Notes:¹ Measured value.² Calculated based on measured hydraulic conductivity per EPA, 1995.³ EPA. 1995. How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites. A Guide for Corrective Action Plan Reviewers.⁽⁴⁾ Frankenberger, W. T. 1999.

cm/s - centimeter per second

cm² - centimeters squared

EPA - U.S. Environmental Protection Agency

g/cc- gram per cubic centimeter

MCB - Marine Corps Base

N/A - not applicable

na - not analyzed

wt. % - percent by weight

TABLE 2-4

**SUMMARY OF BIOLOGICAL PARAMETERS FOR SOIL SAMPLES FROM
WELL BORING 43402-B27/MW5, MCB CAMP PENDLETON, JANUARY 2001**

Sample ID	Depth (feet)	Total Heterotrophic Plate Count (cfu/g)	Hydrocarbon Oxidizing Population (mpn/g)	Total Organic C (mg/kg)	NH ₄ ⁺ -N (mg/kg)	NO ₃ ⁻ -N (mg/kg)	Ortho-P (mg/kg)	C:N:P	pH	Moisture (%)
Optimal Range		>1.0E+03 ^a	N/A	N/A	N/A	N/A	N/A	100:10:1 to 100:1:0.5 ^a	6 to 8 ^a ; 6.5 to 8.5 ^b	12-15 ^b
0024-033	16-16.5	2.25E+05	4.90E+05	2300	9.6	12.8	--	100:1.0:nd	8.5	14.0
0024-034*	25.5-26	1.48E+07	1.70E+07	1300	8.7	16.5	--	100:1.9:nd	8.5	11.6
Detection Limit	N/A	1.00.E+01	1.00.E+01	500	0.5	0.5	0.3	N/A	N/A	N/A

Notes:^a: EPA, 1995.^b: Frankenberger, W.T., 1999.

--: Not Detected

*: Collected below water table

cfu/g: colony forming units per gram soil

EPA: U.S. Environmental Protection Agency

MCB: Marine Corps Base

mg/kg: milligram per kilogram

mpn/g: most probable number per gram soil

NA: not applicable

C:N:P: TOC:(NH₄⁺ + NO₃⁻):P, by mass

TABLE 2-5

**SUMMARY OF WATER LEVEL ELEVATIONS
UST SITE 43402, MCB CAMP PENDLETON, CA**

Monitoring Well ID	Reference Point (toc) Elevation (feet amsl)	Well Screen Interval (feet btoc)	Date Measured	Depth to Water (feet btoc)	Groundwater Elevation (feet amsl)
MW1	252.41	10-30	26-Aug-98 ⁽¹⁾	16.60	236.23
			24-Jan-01	25.41	224.81
			19-Apr-01	25.96	226.45
	252.69 ⁽²⁾		7-Aug-01	26.34	226.35
			24-Oct-01	26.72	225.97
			25-Apr-02	27.52	225.17
			17-Oct-02	28.22	224.47
			21-Apr-03	24.98	227.71
			21-Apr-03	23.53	229.16
			19-Jan-04	24.51	228.18
			6-Jul-04	25.15	227.54
			12-Jan-05	24.71	227.98
MW2 ⁽³⁾	247.82	10-30	26-Aug-98 ⁽¹⁾	17.00	230.82
MW3	250.22	10-35	26-Aug-98 ⁽¹⁾	18.12	232.10
			24-Jan-01	26.88	223.34
			19-Apr-01	27.02	223.20
			7-Aug-01	27.75	222.47
			24-Oct-01	28.16	222.06
			25-Apr-02	28.89	221.33
			17-Oct-02	29.75	220.47
			21-Apr-03	26.77	223.45
			1-Oct-03	25.52	224.70
			19-Jan-04	26.17	224.05
			6-Jul-04	26.97	223.25
			12-Jan-05	24.83	225.39
MW4 ⁽³⁾	242.98	10-30	26-Aug-98 ⁽¹⁾	17.12	225.58

TABLE 2-5

**SUMMARY OF WATER LEVEL ELEVATIONS
UST SITE 43402, MCB CAMP PENDLETON, CA**

Monitoring Well ID	Reference Point (toc) Elevation (feet amsl)	Well Screen Interval (feet btoc)	Date Measured	Depth to Water (feet btoc)	Groundwater Elevation (feet amsl)
MW5	251.87	14.5-29.5	24-Jan-01	25.40	226.47
			19-Apr-01	25.56	226.31
			7-Aug-01	26.18	225.69
			24-Oct-01	26.54	225.33
			25-Apr-02	27.34	224.53
			17-Oct-02	28.12	223.75
			21-Apr-03	24.90	226.97
			1-Oct-03	23.47	228.40
			19-Jan-04	24.44	227.43
			6-Jul-04	25.10	226.77
			12-Jan-05	24.61	227.26
MW6	247.89	14.5-29.5	24-Jan-01	25.56	222.33
			19-Apr-01	25.04	222.85
			7-Aug-01	26.34	221.55
			24-Oct-01	26.74	221.15
			25-Apr-02	27.53	220.36
			17-Oct-02	28.49	219.40
			21-Apr-03	25.43	222.46
			1-Oct-03	24.31	223.58
			19-Jan-04	24.81	223.08
			6-Jul-04	25.76	222.13
			12-Jan-05	25.55	222.34
MW7	250.91	13.5-33.5	24-Jan-01	25.35	225.56
			19-Apr-01	25.50	225.41
			7-Aug-01	26.12	224.79
			24-Oct-01	26.52	224.39
			25-Apr-02	27.34	223.57
			17-Oct-02	28.12	222.79
			21-Apr-03	24.82	226.09
			1-Oct-03	23.51	227.40
			19-Jan-04	24.40	226.51
			6-Jul-04	25.12	225.79
			12-Jan-05	24.70	226.21

TABLE 2-5

**SUMMARY OF WATER LEVEL ELEVATIONS
UST SITE 43402, MCB CAMP PENDLETON, CA**

Monitoring Well ID	Reference Point (toc) Elevation (feet amsl)	Well Screen Interval (feet btoc)	Date Measured	Depth to Water (feet btoc)	Groundwater Elevation (feet amsl)
MW8	249.89	14.5-34.5	24-Jan-01	26.20	223.69
			19-Apr-01	26.32	223.57
			7-Aug-01	26.98	222.91
			24-Oct-01	27.33	222.56
			25-Apr-02	28.09	221.80
			17-Oct-02	28.91	220.98
			21-Apr-03	25.73	224.16
			1-Oct-03	24.63	225.26
			19-Jan-04	25.35	224.54
			6-Jul-04	26.11	223.78
			12-Jan-05	25.76	224.13

Notes:

(1) - Measurement taken by Brown and Caldwell (1999)

(2) - Top of well casing resurveyed in August 2001

(3) - abandoned

amsl - above mean sea level

btoc - below top of casing

MCB - Marine Corps Base

toc - top of casing

UST - Underground Storage Tank

TABLE 2-6

**SUMMARY OF GROUNDWATER RESULTS
FOR EVALUATION OF NATURAL ATTENUATION
UST SITE 43402, MCB CAMP PENDELTON, CA**

Monitoring Well ID	Date Sampled	Sample ID	Chloride ⁽¹⁾ (mg/L)	Nitrate ⁽¹⁾ (mg/L)	Sulfate ⁽¹⁾ (mg/L)	Iron (II) ⁽²⁾ (mg/L)	Dissolved Oxygen ⁽³⁾ (mg/L)	ORP ⁽³⁾ (mV)
MW1	8-Aug-01	0024-248	163	0.823	85.4	na	2.88	111
	24-Oct-01	0024-314	na	na	na	na	2.27	159
	25-Apr-02	0024-367	na	na	na	na	2.43	104
	18-Oct-02	0024-443	na	na	na	na	**	**
	21-Apr-03	0024-471	176	1.36	71.9	--	1.98	249
	2-Oct-03	0024-528	185	1.27	76.8	--	2.48	163
	19-Jan-04	0063-045	159	1.22	72.7	--	2.84	150
	8-Jul-04	0081-042	180	1J	68	--	3.4	49
	13-Jan-05	0081-066	180	1J	69	--	2.32	113
MW3	24-Jan-01	0024-071	142	2.59	56.3	--	4.79	149
	19-Apr-01	0024-116	117	2.45	56.6	--	3.85	223
	7-Aug-01	0024-241	114	2.31	47.6	--	4.67	112
	24-Oct-01	0024-312	109	2.38	58.4	--	5.26	49
	25-Apr-02	0024-363	118	2.22	50.4	--	4.79	99
	18-Oct-02	0024-437	139	2	54.8	--	4.30	158
	21-Apr-03	0024-472	99.8	1.69	42.5	--	5.80	247
	1-Oct-03	0024-527	131	1.81	51.9	--	4.87	140
	19-Jan-04	0063-043	92.3	2.02	47.5	--	5.64	135
	7-Jul-04	0081-040	87	2J	44	--	5.66	114
	12-Jan-05	0081-063	54	2	31	--	5.79	97
MW5	24-Jan-01	0024-072	181	0.042 J	43.5	1.7	1.02	-135
	20-Apr-01	0024-120	165	--	48.8	0.5	0.12	-136
	8-Aug-01	0024-243	124	--	114	2.4	0.22	-146
	8-Aug-01	0024-244 (Dup)	113	--	133	na	na	na
	24-Oct-01	0024-308	131	--	43	4.2	0.26	-163
	26-Apr-02	0024-366	148	--	24.7	4.0	0.22	-119
	18-Oct-02	0024-438	135	0.173	55.1	--	**	**
	22-Apr-03	0024-477	166	--	27.9	4.1	0.00	-73
	2-Oct-03	0024-532	163	--	5.38	1.3	0.31	-174
	20-Jan-04	0063-048	156	--	24.5	5.4	0.09	-131
	8-Jul-04	0081-046	160	--	34	3.2	0.75	-136
	13-Jan-05	0081-069	170	0.7J	47	3.5	0.22	-132

TABLE 2-6

**SUMMARY OF GROUNDWATER RESULTS
FOR EVALUATION OF NATURAL ATTENUATION
UST SITE 43402, MCB CAMP PENDELTON, CA**

Monitoring Well ID	Date Sampled	Sample ID	Chloride ⁽¹⁾ (mg/L)	Nitrate ⁽¹⁾ (mg/L)	Sulfate ⁽¹⁾ (mg/L)	Iron (II) ⁽²⁾ (mg/L)	Dissolved Oxygen ⁽³⁾ (mg/L)	ORP ⁽³⁾ (mV)
MW6	25-Jan-01	0024-077	na	na	na	na	2.11	-148
	19-Apr-01	0024-115	148	0.375	54.6	--	2.72	-129
	7-Aug-01	0024-240	105	0.409	40.5	--	2.90	122
	24-Oct-01	0024-310	114	0.606	50.1	--	**	**
	25-Apr-02	0024-364	117	0.195	69.2	--	**	**
	18-Oct-02	0024-438	135	0.173	55.1	--	**	**
	21-Apr-03	0024-473	132	--	44.9	--	0.00	268
	1-Oct-03	0024-526	138	--	46.1	--	1.34	141
	19-Jan-04	0063-042	140	--	45.8	--	0.57	-24
	7-Jul-04	0081-039	130	--	44	--	1.68	67
	12-Jan-05	0081-064	140	0.6J	47	--	0.34	11
MW7	25-Jan-01	0024-079	na	na	na	na	2.11	-148
	19-Apr-01	0024-117	na	na	na	--	2.72	-129
	19-Apr-01	0024-118 (Dup)	na	na	na	na	na	na
	7-Aug-01	0024-246	na	na	na	--	2.90	122
	24-Oct-01	0024-311	na	na	na	--	**	**
	25-Apr-02	0024-360	na	na	na	--	**	**
	25-Apr-02	0024-361 (Dup)	na	na	na	na	na	na
	17-Oct-02	0024-436	na	na	na	--	0.00	-109
	22-Apr-03	0024-476	182	--	53.3	--	0.00	-42
	2-Oct-03	0024-530	171	--	58.6	--	0.21	-94
	20-Jan-04	0063-047	158	--	54.8	5.2	0.30	-97
	8-Jul-04	0081-045	160	--	55	3.4	0.85	-121
	13-Jan-05	0081-068	170	0.7J	60	2.5	0.31	-108

TABLE 2-6

**SUMMARY OF GROUNDWATER RESULTS
FOR EVALUATION OF NATURAL ATTENUATION
UST SITE 43402, MCB CAMP PENDELTON, CA**

Monitoring Well ID	Date Sampled	Sample ID	Chloride ⁽¹⁾ (mg/L)	Nitrate ⁽¹⁾ (mg/L)	Sulfate ⁽¹⁾ (mg/L)	Iron (II) ⁽²⁾ (mg/L)	Dissolved Oxygen ⁽³⁾ (mg/L)	ORP ⁽³⁾ (mV)
MW8	25-Jan-01	0024-075	182	0.050 J	34.1	3.0	1.11	-75
	25-Jan-01	0024-076 (Dup)	183	0.038 J	31.1	3.2	na	na
	19-Apr-01	0024-119	182	--	32.7	4.0	0.49	-56
	8-Aug-01	0024-247	159	0.034 J	41.3	3.6	--	-98
	24-Oct-01	0024-313	143	0.086J	48.1	5.0	0.35	-119
	25-Apr-02	0024-362	161	--	50.3	4.4	0.19	-90
	18-Oct-02	0024-441	179	--	56.1	6.8	0.00	-71
	22-Apr-03	0024-475	189	--	49.4	3.8	0.00	-44
	2-Oct-03	0024-529	201	--	49.5	3.2	0.30	-64
	20-Jan-04	0063-046	163	--	43.4	5.6	0.23	-93
	8-Jul-04	0081-043	180	--	39	3.4	0.61	-146
	13-Jan-05	0081-067	180	0.9J	44	2.8	0.48	-118
Reporting Limits			0.2	0.1	0.5	(4)	(4)	(4)

Notes:

- (1) - Analyzed by EPA Method 300.0
 (2) - Ferrous iron by Hach IR-18C field kit
 (3) - Parameters measured using field instrument
 (4) - Not applicable for field measurements
 ** - No data because the well went dry
 -- - not detected above laboratory reporting limit
 J - estimated value; value falls between the method detection limit and project reporting limit

- Dup - duplicate sample
 EPA - U.S. Environmental Protection Agency
 MCB - Marine Corps Base
 mg/L - milligrams per liter
 mV - millivolts
 na - not analyzed
 ORP - oxidation/reduction potential
 UST - Underground Storage Tank

TABLE 2-7

**SUMMARY OF BIOVENT SYSTEM OPERATION AND MAINTENANCE DATA
UST SITE 43402, MCB CAMP PENDLETON**

Date	Air Injection Rate (scfm)		TEP Height (feet from top of brass)	Influent Gas Concentration			MW5/BV-3			New Probe #1/#2			New Probe #3			BV-1/BV-2			Ctr (hrs)
				N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	
7/22/2004	ON	10																	
7/30/2004	ON	10	0.11	500				19.6/19.1	0/0.3		19.9/12.4	0/5.2					18.3/18.6	0/0	
8/4/2004	OFF						585/502	4.7/2.1	4.2/6.6	250/496	1.7/12.3	10.3/5.1				520/518	1.8/4.6	5.3/3.4	
8/5/2004	ON	10																	
8/11/2004	ON	10																	
8/12/2004	OFF																		
8/17/2004	ON	10																	8163
8/18/2004	OFF																		8215
8/30/2004	ON	10	0.09	460															
9/7/2004	ON	10	0.04	491	19.1	0	570/550	18.9/19.2	0/0	481/143	18.6/12.5	0/5.2				491/491	19.1/18.5	0/0	8406
9/13/2004	OFF		0.29				545/490	2.7/0.7	5.4/7.7	123/202	1.5/11.5	11.4/5.1				570/519	0.2/1.0	8.6/7.0	
9/14/2004	ON	10																	
9/23/2004	ON		0.24				481/462	19.6/19.3	0/0.3	472/40	20.4/12.8	0/3.0				479/481	19.9/19.9	0/0	8649
10/1/2004	OFF																		
10/7/2004	ON	10		489	19.3	0	493/485	19.3/19.1	0/0	487/41	18.9/13.0	0/5.2				489/489	19.3/19.2	0/0	8793
10/15/2004	OFF		0.26				515/35	0.5/0.0	8.4/10.6	44/66	0.5/10.3	14.5/6.3				447/470	1.2/6.3	11.1/5.0	8793
10/22/2004	ON																		8887
system down																			
11/23/2004	ON	8	0.2																
12/1/2004	OFF	10	0.2					0.0/0.3	9.8/9.7		0.7/7.6	13.2/7.5					0.8/1.0	8.6/7.4	8488
12/10/2004	ON	10					450/8.2	19.9/18.4	0.0/1.1	491.1/67.0	20.0/9.8	0.0/8.2				485/490	20.0/20.0	0.0/0.0	
12/17/2004	OFF		0.2	456.3			57.8/61.6	0.5/8.0	9.1/4.8	35.4/40.5	2.2/7.7	11.9/8.7				50.9/408	0.2/1.0	12.1/7.0	8704
system down																			
1/31/2005	system activated																		
2/14/2005	ON	9		457			441/439	19.7/18.3	0.0/1.5	433/102	19.3/1.5	0.01/12.3				448/449	19.4/19.1	0.0/0.6	9106

Final Corrective Action Plan

UST Site 43402

MCB Camp Pendleton

DCN: SES-TECH-05-0126

CTO No. 0004, Revision 1, 09/26/05

TABLE 2-7

**SUMMARY OF BIOVENT SYSTEM OPERATION AND MAINTENANCE DATA
UST SITE 43402, MCB CAMP PENDLETON**

Date	Air Injection Rate (scfm)		TEP Height (feet from top of brass)	Influent Gas Concentration			MW5/BV-3			New Probe #1/#2			New Probe #3			BV-1/BV-2			Ctr (hrs)
				N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	
2/21/2005	OFF			460															9107
2/28/2005	ON	10					8.4/110.3	20.0/18.2	0.2/1.6							4.0/3.2	20.2/19.3	0.0/0.7	9273
3/7/2005	ON	10		464			70.7/477	7.0/7.3	1.1/5.2	19.2/509	19.0/12.1	6.6/5.5				37.9/109.5	8.3/7.8	5.2/4.7	9274
3/14/2005	ON	8.5		28.1			430/496	19.6/17.0	0.3/2.4	43.7/492	18.3/1.5	0.7/12.5				26.4/495	20.4/18.6	0.0/1.2	9442
3/28/2005	OFF			0			109.5/65.7	0.3/0.2	10.6/12.0	24.1/495	4.0/1.3	10.1/11.6	46.3	0.1	13.1	48.4/56.0	1.7/0.1	11.9/10.0	9442
4/5/2005	OFF						568/579	14.0/8.8	21/9.1	567/548	14.1/1.2	3.4/8.5	73.7	0.5	15.3	543/577	8.1/14.7	3.2/2.8	9583
4/12/2005	ON	10					48.3/45.9	0.2/1.0	10.1/11.9	30.8/482	19.1/11.3	0.4/0.2	43.5	0.3	13.3	44.2/44.7	0.9/0.3	11.0/10.8	9583
4/19/2005	ON	10		0			68.9/506	18.4/1.4	1.3/13.6	6.2/443	18.2/0.1	1.3/11.5	220	0.4	14.5	0.9/507	203/9.1	0.0/6.0	9750
4/26/2005	OFF			463															
5/10/2005	ON	10		0.4			29.9/475	17.4/0.7	1.8/14.8	3.6/1.4	17.4/20.1	1.6/0.0	426	0.2	14.7	1.2/458	20.1/2.6	0.00/12.6	10068
5/17/2005	OFF						75.5/143	0.3/0.5	12.3/15	5.6/0.2	10.4/19.9	4.6/0.0	40.9	0.2	14.7	40.0/49.0	0.2/3.2	12.1/15.4	10068
5/24/2005	ON	6		390			468/49.8	11.3/0.5	5.7/15.1	20.3/1.9	18.9/20.0	0.6/0.0	48.5	0.2	15.3	329/49.1	20.2/0.3	0.0/15.7	10253
5/31/2005	ON	10					109/32.7	0.4/0.1	14.2/15.5	23.2/0.7	13.5/19.6	2.8/0.0	36.3	0.1	15.4	27.0/39.1	1.3/1.1	11.7/14.0	10254
6/14/2005	OFF			450			68.5/453	7.0/7.5	1.3/5.4	18.9/458	8.7/13.0	6.6/5.5	428	0.2	14.6	36.8/109.5	8.4/7.5	5.3/4.6	10590
6/22/2005	ON	10					294/303	0.3/1.9	16.2/14.5	2.7/3.3	13.8/19.4	2.6/0.0	518	0.2	15.8	49.3/59.1	0.9/0.2	13.6/17.0	10590
6/30/2005	OFF						520/515	2.2/0.2	15.6/17.6	467/54	14.6/19.9	1.5/0.0	118	0.2	16.2	519/518	4.5/0.2	10.4/19.5	10594

Notes:N₂O - nitrous oxide%O₂ - percent oxygen%CO₂ - percent carbon dioxide

ppmv - parts per million in volume

scfm - standard cubic feet per minute

UST - Underground Storage Tank

MCB - Marine Corps Base

TABLE 2-8

**COMPARISON OF VERIFICATION SOIL SAMPLE RESULTS WITH HISTORICAL SOIL SAMPLE RESULTS
UST SITE 43402, MCB CAMP PENDLETON**

Sample Location	Boring Number	Sample I.D.	Date Sampled	Sample Depth (feet)	TPH-d (mg/kg)	SPLP/TPH-d (µg/L)	VOCs (µg/kg)				SPLP/VOCs (µg/kg)	PAHs (µg/kg)		SPLP/PAHs (µg/kg)
							Methylene Chloride	Acetone	MIBK	Total Xylenes	Methylene Chloride	Dibenz(a,h)anthracene	Phenanthrene	
North of Former Tank Cavity	VSF-1	0081-0080	July 6, 2005	20	3,700	60	96	--	--	--	1	--	--	--
	BV-4 ¹	0063-60	April 20, 2004	21.5	28,000	NA	NA	NA	NA	NA	NA	NA	NA	NA
Southeast of Former Tank Cavity	VSF-2	0081-081	July 6, 2005	22	760	72	5	48	--	--	1	--	--	--
	BV-6 ²	0063-067	April 21, 2004	21.5	6,700	NA	NA	NA	NA	NA	NA	NA	NA	NA
East of Former Tank Cavity	VSF-3	0081-082	July 6, 2005	19	12 J	0.3	5	20 J	1 J	--	2 J	3 J	--	--
	B-4 ³	43402-B4-20	August 1998	20	8,606 ⁴	NA	NA	NA	NA	0.466	NA	--	2.5	NA

Notes:¹ - Biovent injection well.² - Biovent observation well.³ - Boring was drilled and sampled during the 1998 Site Assessment⁴ - Mobile laboratory result. Stationary laboratory result was 2,970 mg/kg.

J - Estimated value.

µg/kg - microgram per kilogram

mg/kg - milligram per kilogram

µg/L - microgram per liter

MIBK - 4-methyl-2-pentanone

TABLE 2-9

**COMPARISON OF NATURAL ATTENUATION PARAMETER VERIFICATION SOIL SAMPLE RESULTS WITH
HISTORICAL SOIL SAMPLE RESULTS
UST SITE 43402, MCB CAMP PENDLETON**

Sample Location	Soil Boring ID	Date Sampled	Sample I.D.	Depth (feet below grade)	Ammonia-Nitrogen (mg/kg)	Nitrate-Nitrogen (mg/kg)	Orthophosphate- Phosphorous (mg/kg)	Hydrocarbon-Oxidizing Microbial Population (MPN/g)
North of Former Tank Cavity	VSB-1	July 6, 2005	0081-0080	21	<5.0	4.8	14.8	4.3×10^4
	BV-4 ⁽¹⁾	April 20, 2004	0063-062	22	10.2	10.4	<2.0	4.3×10^1
Southeast of Former Tank Cavity	VSB-2	July 6, 2005	0081-081	21	<5.0	4.2	5.0	9.3×10^1
	BV-6 ⁽²⁾	April 21, 2004	0063-066	20	13.7	18.5	<2.0	6.7×10^1

Notes:

mg/kg - milligrams per kilogram

MPN-g - Most Probable Number/gram

(1) - Biovent injection well

(2) - Biovent observation well

TABLE 5-1

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR SOIL,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
Active Remediation	<i>In situ</i> biological treatment.	Bioventing/biosparging: Introduce oxygen into the impacted soils in both the vadose zone and saturated zone, respectively, to increase the biological activity of native microorganisms.	Very low to High: Oxygen is typically the limiting factor for aerobic bioremediation, and adding oxygen has been shown to be effective to reduce concentrations of petroleum contaminants adsorbed to soil particles both above and below the water table. Results of bioventing already completed at the site (see Section 2.9) indicate that it is effective in introducing oxygen (and nutrients) into the vadose zone. However, the impacted soils located below the water table have a very low permeability ($3.54\text{E-}12\text{ cm}^2$, Table 2-3), which is below the range considered effective for biosparging ($10\text{E-}10\text{ cm}^2$) (EPA, 1995). Biosparging is considered marginally effective to ineffective in soils with permeabilities below $10\text{E-}10\text{ cm}^2$ (EPA, 1995).	Difficult to Moderately Easy: Bioventing/biosparging are conventional, well-known technologies, and there are injection and monitoring wells already installed at the site that can continue to be used. However, biosparging in the low permeable soils below the water table would be difficult. Numerous injection wells on a tight grid pattern would be required with extensive piping around the 43 Area mess hall loading dock area.	Moderate: Depends on the number of biosparge wells required and the length of time it would take for contaminant levels to drop in the low permeability saturated zone. It is conservatively assumed that 5+ years of bioventing/biosparging may be required.	Eliminated: Even though the bioventing already conducted at the site indicated that both oxygen and nutrients can effectively be injected into the vadose zone, this alternative is eliminated due to the low-permeability soils in the saturated zone. With the low-permeability saturated zone soils, implementing biosparging will be difficult, and may not be effective.

TABLE 5-1

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR SOIL,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
Active Remediation	Removal.	Excavation with off-site disposal of remaining impacted soils in both the vadose zone and the saturated zone.	High: Provides long-term effectiveness and permanence. Provides protection of human health and the environment by reducing or eliminating the volume of contaminated soils.	Difficult: Excavation is a conventional and well-established technology; however, the remaining impacted vadose zone soils are located beneath numerous underground utilities, and the impacted saturated zone soils are located up to 35 feet deep adjacent to and beneath numerous underground utilities. Extensive shoring and utility rerouting would be required. In addition, saturated zone soils below the former tank cavity are currently beneath the cement slurry backfill (26 feet deep) used during the vadose zone soil excavation (see Section 2.6).	High: An very extensive effort would be required to excavate contaminated soil up to 35 feet deep around numerous utilities, adjacent to Building 43402, and through 26 feet of cement slurry backfill. Extensive shoring and utility rerouting would be required.	Retained: Even though excavation would be difficult and expensive to implement, it is considered the best active remedial alternative available for the site.

TABLE 5-1

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR SOIL,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
Active Remediation	<i>In situ</i> chemical treatment.	Chemical oxidation: Introduce a chemical oxidant to either destroy or degrade contaminants.	High: Where implementable, this technology has been shown to remediate hydrocarbons in both vadose zone and saturated zone soils. The oxidants used are readily available and treatment time is usually measured in months, as opposed to years.	Difficult to Not Implementable: Geotechnical analyses of soils indicate that impacted saturated soils have very low permeability, which may not allow the oxidants to infiltrate the formation. A pilot test would be recommended. In addition, this technology is not recommended for impacted soils near underground utilities or buildings due to exothermic reactions generated.	High: Potentially extensive drilling and monitoring activities would increase costs.	Eliminated: Based on the technology being difficult to implement, or potentially not implementable at all. The low permeable saturated soils, and the numerous nearby underground utilities, are not well suited for <i>in situ</i> chemical oxidation.

TABLE 5-1

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR SOIL,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
No Further Action	Not applicable.	Not applicable.	High: Natural attenuation has been shown to be effective at petroleum sites for the long-term, permanent removal of contaminants. Impacted soils in the vadose zone were physically removed to the extent practical (455 cubic yards), and remaining impacted soils that could not be removed due to nearby utilities and Building 43402 were treated for 12 months with bioventing (see Section 2.9). The impacted soils located in the saturated zone do not appear to be impacting groundwater to any significant extent, if at all. The groundwater plume has shrunk and groundwater contaminant levels continue to decrease. Site data strongly indicate natural attenuation is occurring, and it is believed natural attenuation will continue to occur.	Easy: No additional soil remedial activities would be performed.	Low: Since there would be no additional soil remediation, there would be no additional soil remediation costs. The only cost would be associated with abandoning the groundwater monitoring wells after regulatory site closure.	Retained: Based on historical site data and current site conditions, it is believed the remaining petroleum impacted soils (in both the vadose zone and the saturated zone) will attenuate naturally. Data from several years of groundwater monitoring have shown the groundwater plume has shrunk, and overall contaminant levels have decreased, indicating the remaining soil contamination both above and below groundwater is not impacting groundwater to any significant extent, if at all. In addition, site data strongly indicate natural attenuation is occurring, and it is believed natural attenuation will continue to occur.

Notes:

EPA – U.S. Environmental Protection Agency
 MCB – Marine Corps Base
 UST – Underground Storage Tank

TABLE 5-2

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR GROUNDWATER,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
No Further Action	Not applicable.	Not applicable.	High: Hydrocarbon constituents are readily biodegradable, the plume is stable and shrinking. The nearest municipal supply well is 3.7 miles away. Analytical data indicate that hydrocarbon-degrading bacteria are present in site soils at levels above those considered optimal by the EPA.	Easy: No remedial activities would be performed. Site closure would be complete after the destruction of the existing groundwater monitoring wells.	Very low: Costs to destroy existing wells would be relatively low.	Retained: Assumes site closure would be warranted under existing conditions.
Limited Action	Remediation by Monitored Natural Attenuation.	Groundwater monitoring program to verify that contaminant levels are decreasing.	High: Hydrocarbon constituents are readily biodegradable, the plume is stable and shrinking. The nearest municipal supply well is 3.7 miles away. Analytical data indicate that hydrocarbon-degrading bacteria are present in site soils at levels above those considered optimal by the EPA.	Moderately Easy: Consists of periodic groundwater monitoring to assess contaminant disappearance.	Moderate: Depends on length of time required for contaminant levels to drop. It is conservatively assumed that 3 years of monitoring may be required.	Retained: Relatively easy to implement and natural processes have been shown to be effective at similar sites.

TABLE 5-2

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR GROUNDWATER,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
Active Remediation	<i>In situ</i> biological treatment.	Biosparging: Introduce oxygen into the saturated zone by pumping air into the subsurface.	Low: Oxygen is typically the limiting factor for aerobic bioremediation and providing oxygen has been shown to be effective at similar sites; however, effectiveness is only achieved if oxygen reaches the contaminated zone. At this site, saturated zone soil is relatively impermeable. A sample of site soil was analyzed and the intrinsic permeability was less than that considered optimal for biosparging applications (EPA, 1995). Soil at the site would impede biosparging activities.	Moderate to Difficult: Biosparging is a conventional, well-known technology; however, the impacted saturated-zone soil has very low permeability, potentially requiring a large number of sparge wells.	Moderate to high: Potential long-term system O&M (due to low-permeability soils) and potential periodic verification sampling.	Eliminated: Low effectiveness based on low intrinsic permeability of soils. In addition, the effort and costs are not justified based on the low potential for adverse impacts to sensitive receptors or nearby water resources (refer to Section 3.3).
Active Remediation	<i>In situ</i> biological treatment.	Addition of ORC to the contaminated zone. ORC is a patented formulation of magnesium peroxide that produces a slow, sustained source of oxygen in groundwater, which enhances the ability of indigenous microorganisms to degrade fuel hydrocarbons.	High: Oxygen is typically the limiting factor for aerobic bioremediation, and adding oxygen has been shown to be effective at similar sites. Contrary to biosparging, which relies on pressure to push air into the groundwater, ORC provides high concentrations of molecular oxygen that migrate into the contaminated aquifer via diffusion, and thus is not as restricted by low-permeability soils as biosparging.	Moderate: ORC is applied to the subsurface via push-point injection.	Moderate: Costs include purchasing ORC and applying it to the subsurface, with periodic groundwater monitoring. Multiple injections would likely be required.	Eliminated: The effort and costs are not justified based on the low permeability soils and the low potential for adverse impacts from the site to sensitive receptors or nearby water resources (refer to Section 3.3).

TABLE 5-2

**SUMMARY OF SCREENING OF REMEDIAL TECHNOLOGIES FOR GROUNDWATER,
UST SITE 43402, MCB CAMP PENDLETON**

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Cost	Comments
Active Remediation	<i>In situ</i> chemical treatment.	Chemical oxidation: Introduce a chemical oxidant into the saturated zone either to destroy or degrade contaminants.	Moderate to high: Technology has been shown to remediate hydrocarbons in groundwater. The oxidants used are readily available, and treatment time is usually measured in months as opposed to years.	Difficult: Impacted saturated soils have low permeability. Also, this technology is not recommended near underground utilities due to exothermic reactions generated.	Moderate to high: Potentially extensive drilling (due to low permeability soils) and monitoring activities would increase costs.	Eliminated: The effort and costs are not justified based on the low potential for adverse impacts from the site to sensitive receptors or nearby water resources (refer to Section 3.3).
Active Remediation	<i>Ex situ</i> pump and treat.	Groundwater extraction coupled with adsorption/destruction processes such as air stripping, or granular activated carbon, and reintroduction of treated water back into the aquifer.	Low: Readily capable of removing contaminants from extracted water. However, hydrocarbon compounds typically adsorb strongly to soil particles, necessitating system operation over an extensive period of time, and disproportionately large groundwater extraction volumes.	Moderate: <i>Ex situ</i> pump and treat is a conventional and established technology; however, several extraction wells would likely be required, based on the low permeability of the aquifer material.	Very high: High capital and O&M costs. Involves system operation over a potentially long period of time, transport of waste off site and associated permitting.	Eliminated: Low effectiveness and very high cost eliminates pump and treat as a feasible option.

Notes:

EPA – U.S. Environmental Protection Agency

MCB – Marine Corps Base

O&M – operation and maintenance

ORC – Oxygen Release Compound

UST – Underground Storage Tank

TABLE 4-1
PROPOSED CLEANUP OBJECTIVES FOR CONTAMINANTS,
UST SITE 43402, MCB CAMP PENDLETON

Constituent	Groundwater	Soil
TPH-d	100 µg/L ^(a)	SPLP<Groundwater Objective
Benzene	1.0 µg/L ^(b)	SPLP<Groundwater Objective
Toluene	150 µg/L ^(b)	SPLP<Groundwater Objective
Ethylbenzene	680 µg/L ^(b)	SPLP<Groundwater Objective
Total Xylenes	1,750 µg/L ^(b)	SPLP<Groundwater Objective
Benzo[a]pyrene	0.2 µg/L ^(b)	SPLP<Groundwater Objective
Phenanthrene	1.0 µg/L ^(b)	SPLP<Groundwater Objective

Notes:^(a) Secondary taste and odor threshold^(b) Maximum Contaminant Levels

µg/L – micrograms per liter

MCB – Marine Corps Base

SPLP – Synthetic Precipitation Leaching Procedure

TPH-d – total petroleum hydrocarbons quantified as diesel

UST – Underground Storage Tank

FIGURES

DRAWING NO: 05012611.DWG	DCN: SES-TECH-05-0126	APPROVED BY: MC	CHECKED BY: MC	DRAWN BY: MD
CTO: #0004	REV: REVISION 0			DATE: 08/19/05

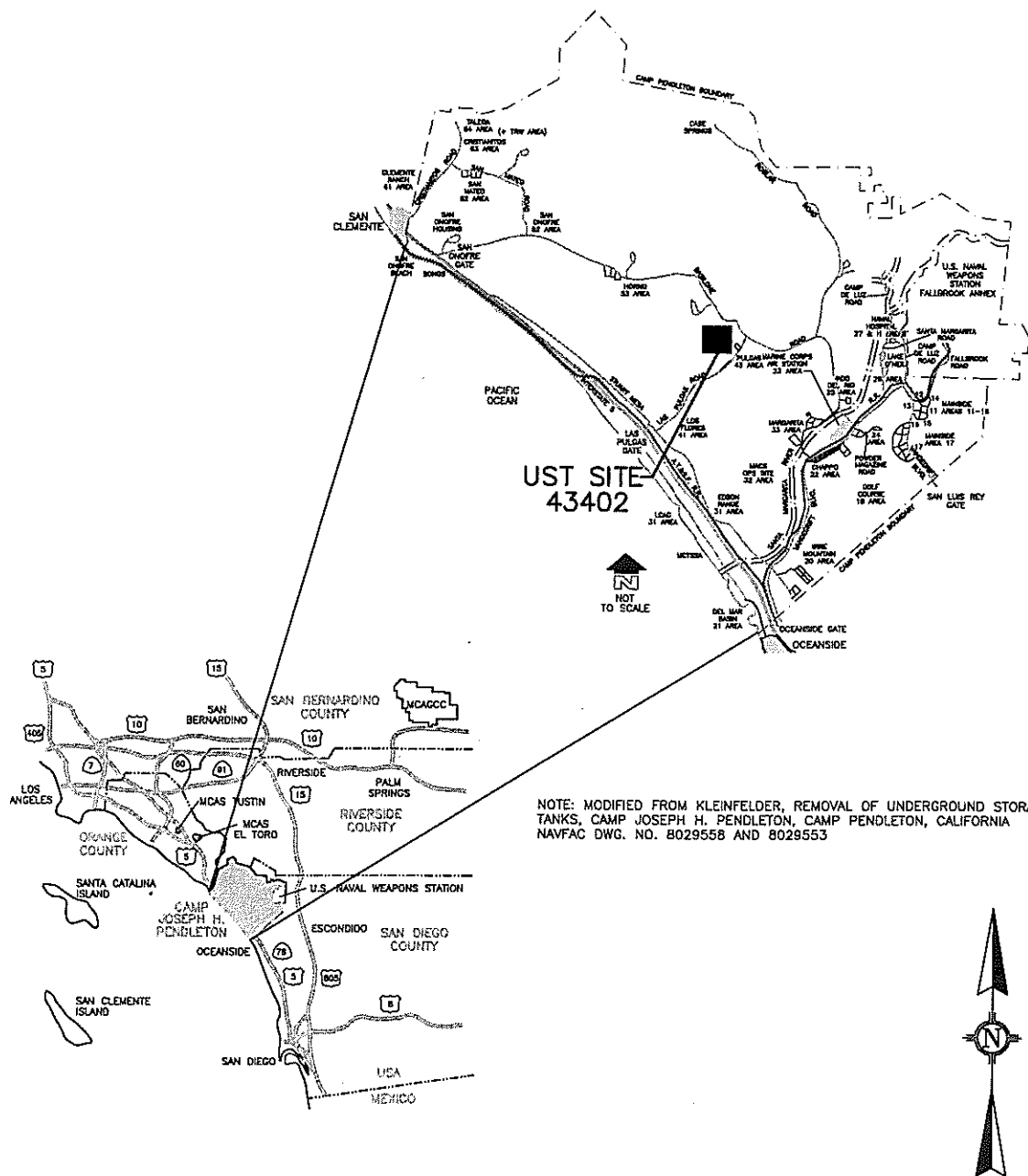
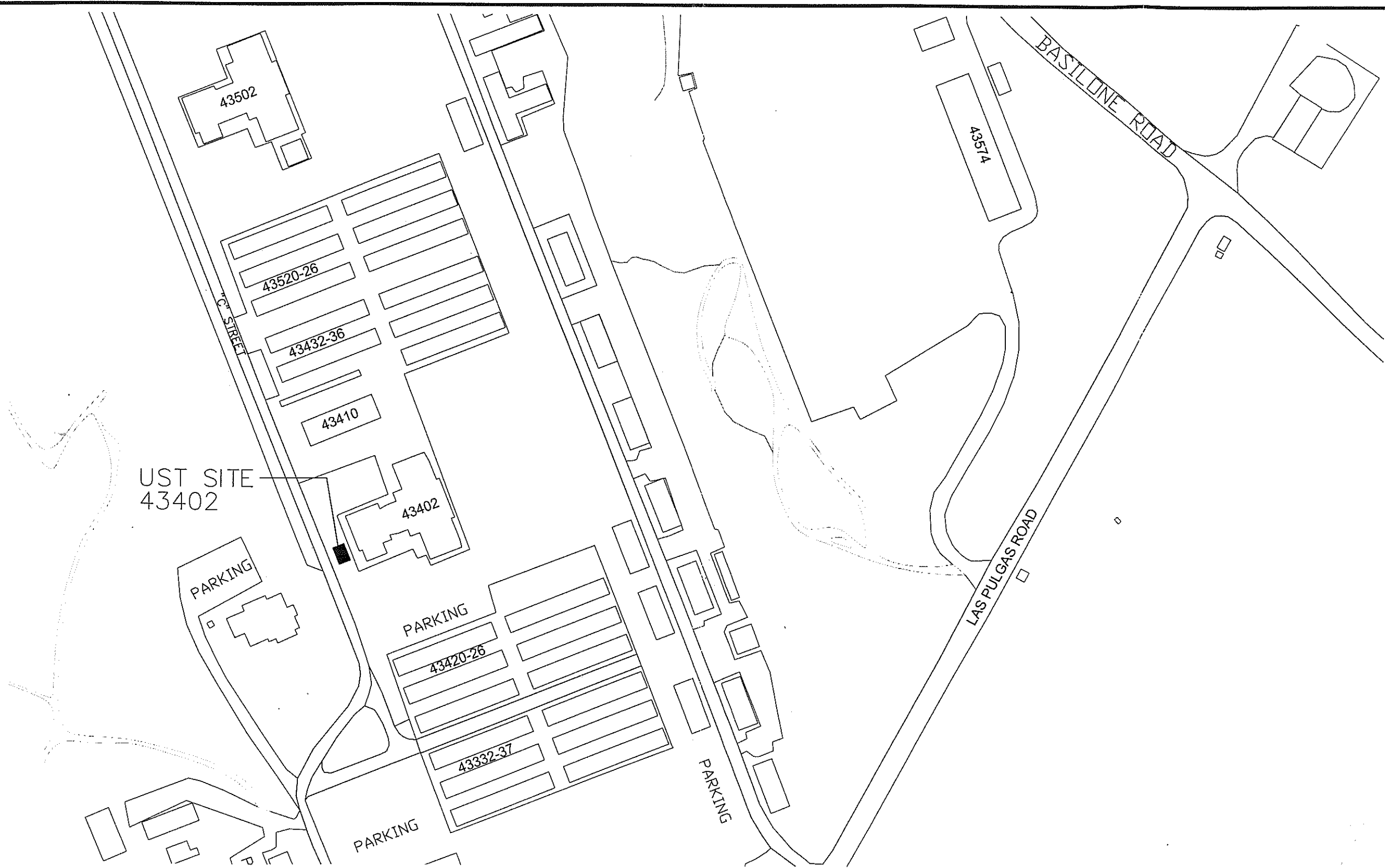


Figure 1-1
SITE VICINITY MAP

MCB CAMP PENDLETON

SES-TECH

DRAWN BY: MD	CHECKED BY: MC	APPROVED BY: MC	DCN: SES-TECH-05-0126	DRAWING NO: 05012612.DWG
DATE: 08/19/05	REV: REVISION 0		CTO: #0004	



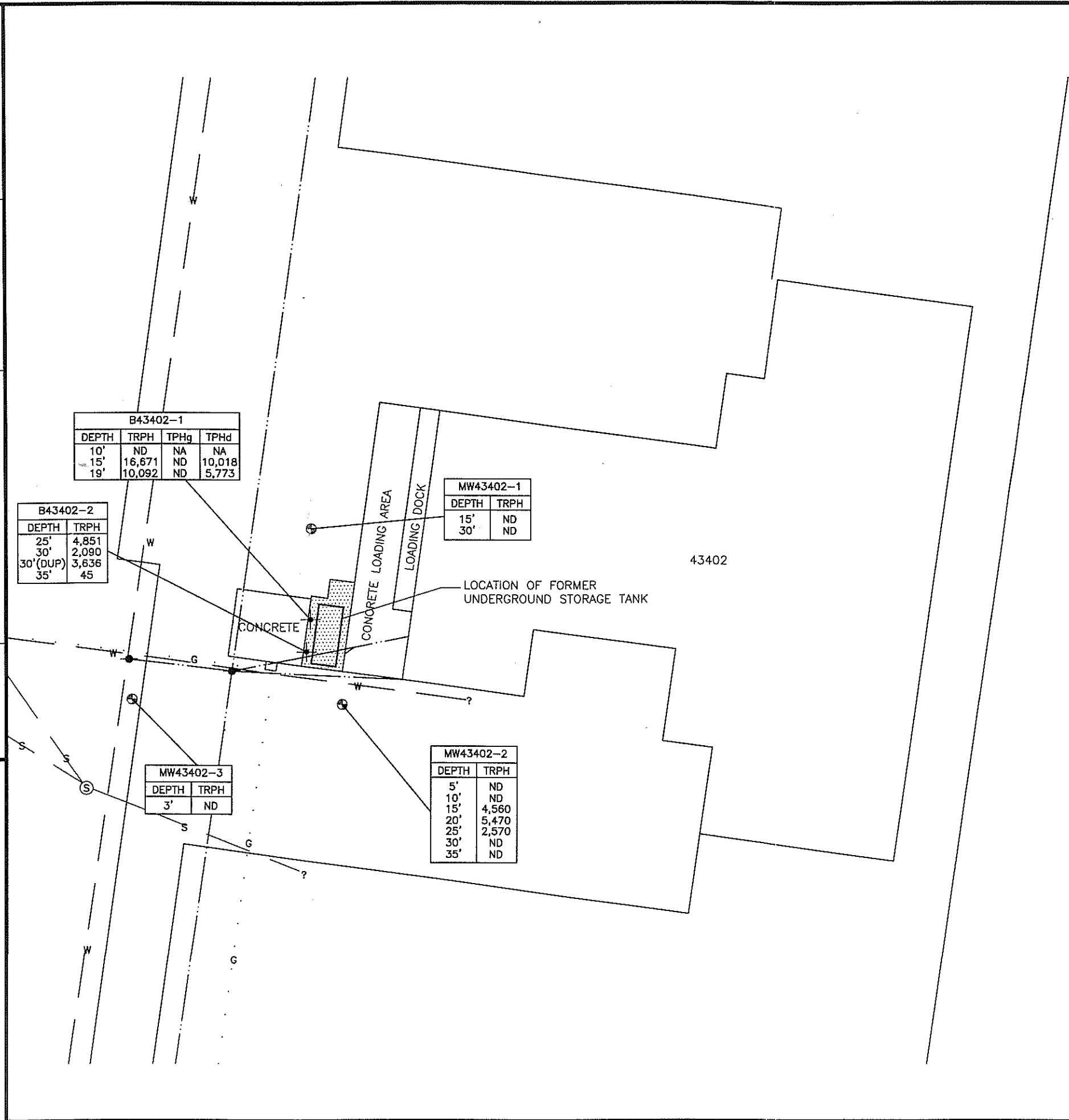
NOTE: MODIFIED FROM KLEINFELDER, REMOVAL OF UNDERGROUND STORAGE TANKS, CAMP JOSEPH H. PENDLETON, CAMP PENDLETON, CALIFORNIA NAVFAC DWG. NO. 8029647.

100 50 0 100 200
SCALE IN FEET



Figure 1-2 UST SITE 43402 LOCATION MAP	
MCB CAMP PENDLETON	
SES-TECH	

DRAWN BY: MD	CHECKED BY: MC	APPROVED BY: MC	DCN: SES-TECH-05-0126	DRAWING NO: 05012621.DWG
DATE: 08/19/05	REV: REVISION 0		CTO #0004	



B43402-1			
DEPTH	TRPH	TPHg	TPHd
10'	ND	NA	NA
15'	16,671	ND	10,018
19'	10,092	ND	5,773

B43402-2	
DEPTH	TRPH
25'	4,851
30'	2,090
30'(DUP)	3,636
35'	45

MW43402-1	
DEPTH	TRPH
15'	ND
30'	ND

MW43402-3	
DEPTH	TRPH
3'	ND

MW43402-2	
DEPTH	TRPH
5'	ND
10'	ND
15'	4,560
20'	5,470
25'	2,570
30'	ND
35'	ND

LEGEND:

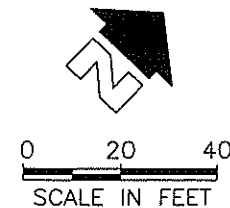
C,E,T
ABOVEGROUND (OVERHEAD) INDICATES APPROXIMATE LOCATION OF ELECTRICAL, TELEPHONE, OR CABLE TV CONDUIT

S W INDICATES APPROXIMATE LOCATION OF UNDERGROUND STORM DRAIN/SEWER OR WATER LINE

G INDICATES APPROXIMATE LOCATION OF UNDERGROUND GAS LINE

B43402-1
SOIL BORING
MONITORING WELL (SUBSEQUENTLY DESTROYED)
UTILITY POLE

TPHg=TOTAL PETROLEUM HYDROCARBONS GASOLINE RANGE (mg/kg)
TPHd=TOTAL PETROLEUM HYDROCARBONS DIESEL RANGE (mg/kg)
TRPH=TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/kg)
ND=NOT DETECTED ABOVE THE DETECTION LIMITS
NA=NOT ANALYZED
DUP=DUPLICATE SAMPLE

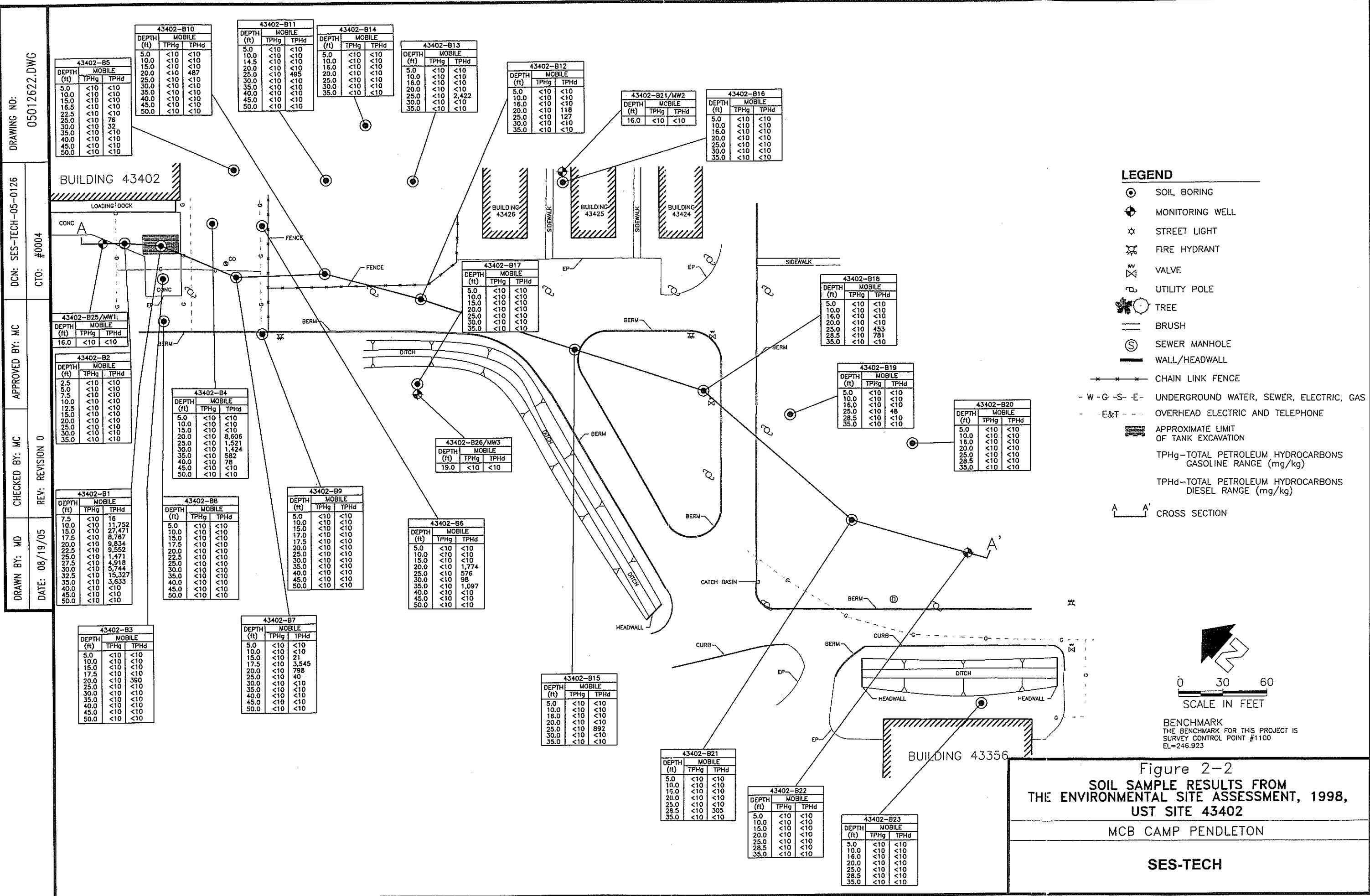


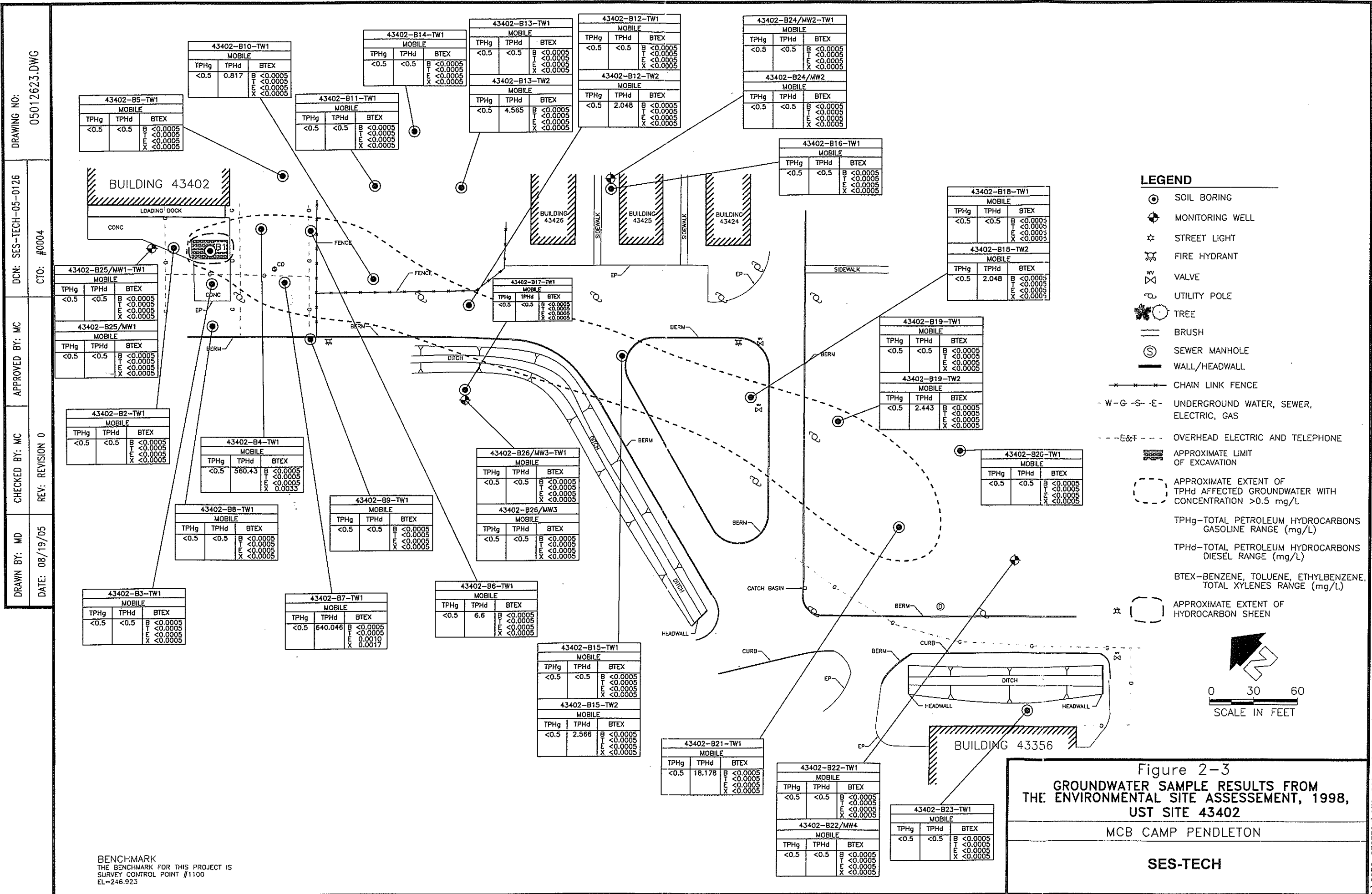
NOTE: MODIFIED FROM KLEINFELDER, REMOVAL OF UNDERGROUND STORAGE TANKS, CAMP JOSEPH H. PENDLETON, CAMP PENDLETON, CALIFORNIA NAVFAC DWG. NO. 8029663

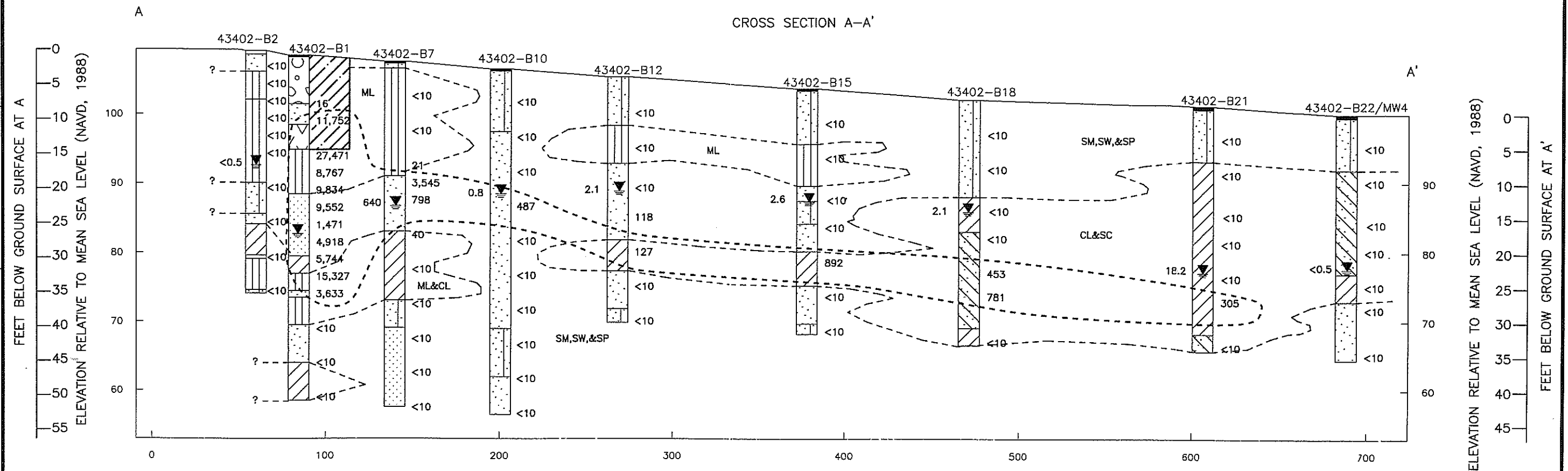
Figure 2-1
SOIL SAMPLE RESULTS FROM
EXPLORATORY DRILLING
1991/1992, UST SITE 43402

MCB CAMP PENDLETON

SES-TECH







LEGEND

SP		POORLY GRADED SAND	SW		WELL GRADED SAND
CL		CLAY			TANK CAVITY BACKFILL
SM		SILTY SAND			GROUNDWATER TABLE
SC		CLAYEY SAND			GROUNDWATER SAMPLE TPHd CONCENTRATION (mg/L)
ML		SILT			

<10 SOIL SAMPLE TPHd CONCENTRATION (mg/kg)

--- LITHOLOGIC CONTACT

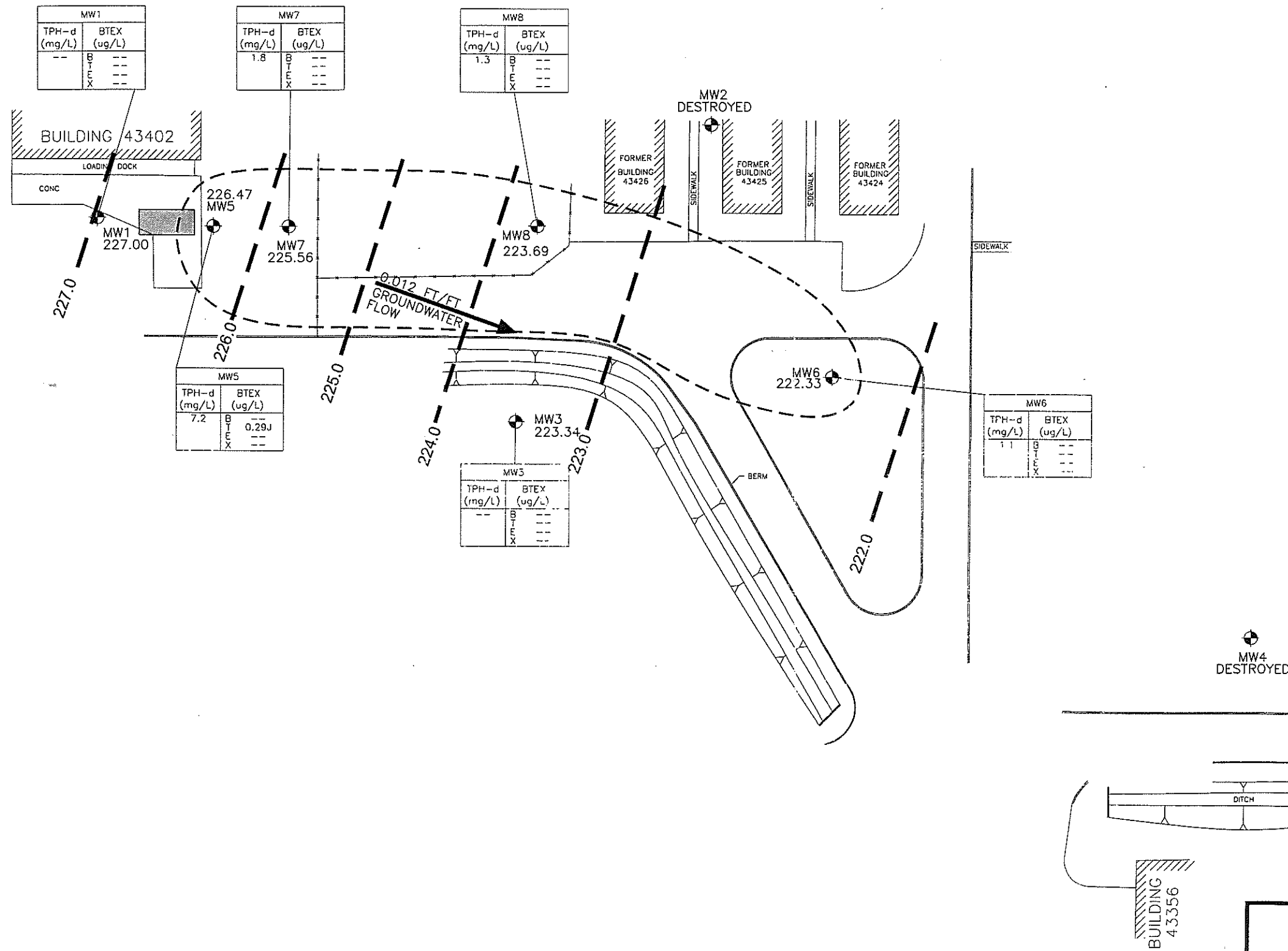
APPROXIMATE EXTENT OF TPHd-AFFECTED SOIL >100 mg/kg

TPHd=TOTAL PETROLEUM HYDROCARBONS DIESEL RANGE

0 30 60
HORIZONTAL SCALE IN FEET

0 15
VERTICAL SCALE IN FEET

Figure 2-4
CROSS SECTION A-A'
FROM THE ENVIRONMENTAL SITE ASSESSMENT,
1998, UST SITE 43402
MCB CAMP PENDLETON
SES-TECH



- ### LEGEND
- MONITORING WELL
 - APPROXIMATE EXTENT OF TPH-d IMPACTED GROUNDWATER ABOVE THE WQO OF 0.1 mg/L.
 - APPROXIMATE LOCATION OF FORMER UNDERGROUND STORAGE TANK
 - WQO WATER QUALITY OBJECTIVE
 - BTEX BENZENE, TOLUENE, ETHYLBENZENE, TOTAL XYLENES
 - TPH-d TOTAL PETROLEUM HYDROCARBONS QUANTIFIED AS DIESEL
 - mg/L MILLIGRAMS PER LITER
 - ug/L MICROGRAMS PER LITER
 - ft/ft FOOT PER FOOT
 - NOT-DETECTED ABOVE LABORATORY REPORTING LIMITS:
 - TPH-d = 0.1 mg/L
 - Benzene = 0.5 ug/L
 - Toluene = 0.5 ug/L
 - Ethylbenzene = 0.5 ug/L
 - Xylenes = 1.5 ug/L

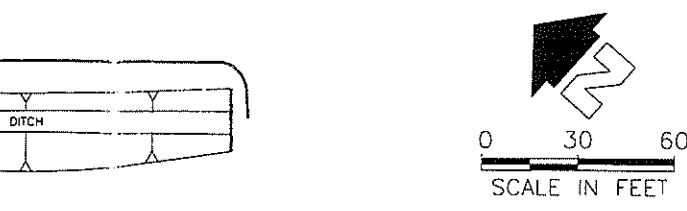
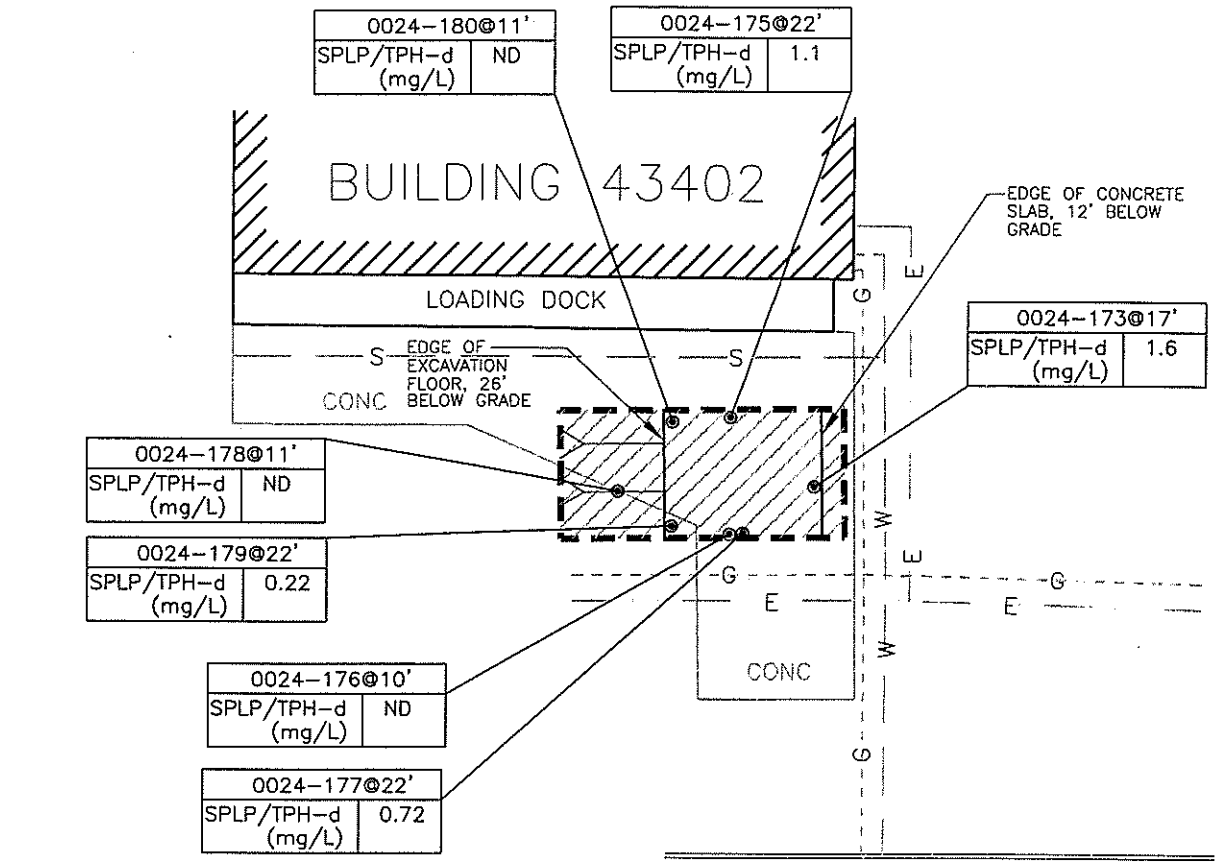


Figure 2-5
GROUNDWATER GRADIENT AND
CONTAMINANT CONCENTRATION MAP
JANUARY 2001, UST SITE 43402
MCB CAMP PENDLETON
SES-TECH

DRAWN BY: MD	CHECKED BY: MC	APPROVED BY: MC	DCN: SES-TECH-05-0126	DRAWING NO: 05012626.DWG
DATE: 08/19/05	REV: REVISION 0		CTO: #0004	



LEGEND

- LIMIT OF SOIL EXCAVATION
- CONFIRMATION SOIL SAMPLE LOCATION
- FEET BELOW GROUND SURFACE
- SPLP** SYNTHETIC PRECIPITATION LEACHATE PROCEDURE
- TPH-d** TOTAL PETROLEUM HYDROCARBONS-QUANTIFIED AS DIESEL IN MILLIGRAMS PER LITER (mg/L).
- ND** NOT DETECTED ABOVE LABORATORY REPORTING LIMITS:
- TPH-d=0.1mg/L**
- W G S E** UNDERGROUND WATER, SEWER, ELECTRIC, GAS
- SLOPE

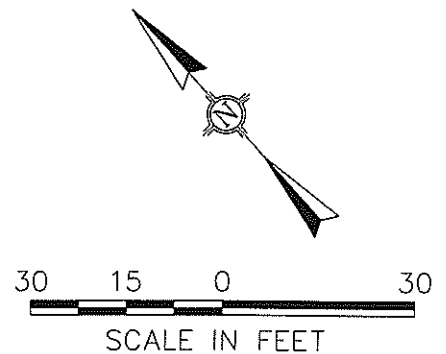
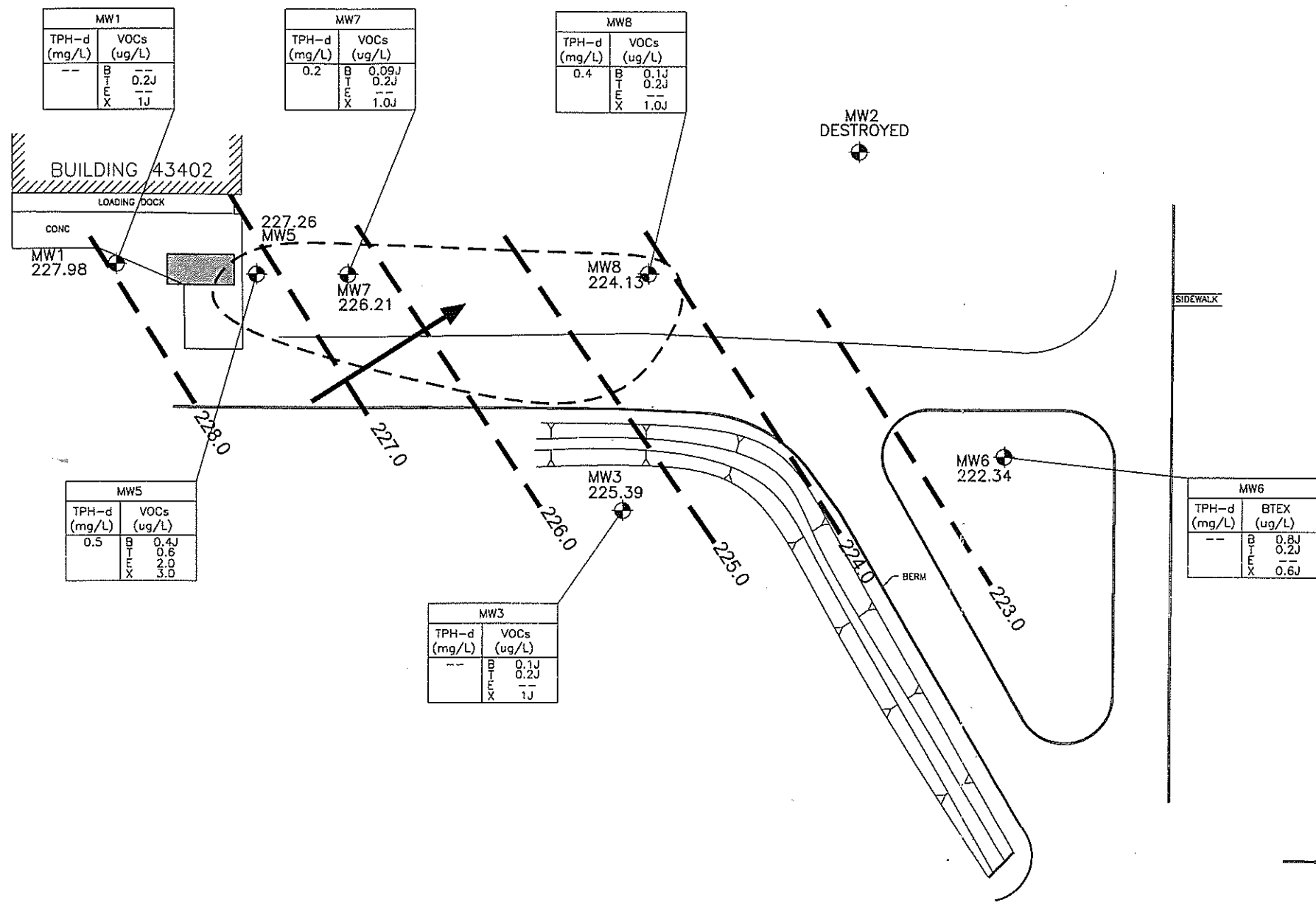


Figure 2-6 UST SITE 43402-SOIL EXCAVATION AREA AND CONFIRMATION SOIL SAMPLE RESULTS

MCB CAMP PENDLETON

SES-TECH



LEGEND

- MW6 222.46 MONITORING WELL ID AND GROUNDWATER ELEVATION
- APPROXIMATE EXTENT OF TPH-d AFFECTED GROUNDWATER ABOVE THE WQO OF 0.1 mg/L
- APPROXIMATE LIMIT OF SOIL EXCAVATION
- 223.0 --- GROUNDWATER ELEVATION CONTOUR
- GROUNDWATER FLOW DIRECTION
- WQO WATER QUALITY OBJECTIVE
- BTEX BENZENE, TOLUENE, ETHYLBENZENE, TOTAL XYLENES
- TPH-d TOTAL PETROLEUM HYDROCARBONS QUANTIFIED AS DIESEL
- mg/L MILLIGRAMS PER LITER
- ug/L MICROGRAMS PER LITER
- J ESTIMATED VALUE
- NOT DETECTED ABOVE LABORATORY REPORTING LIMITS:
 - TPH-d = 0.1 mg/L
 - Benzene = 0.5 ug/L
 - Toluene = 0.5 ug/L
 - Ethylbenzene = 0.5 ug/L
 - Xylenes = 1.5 ug/L

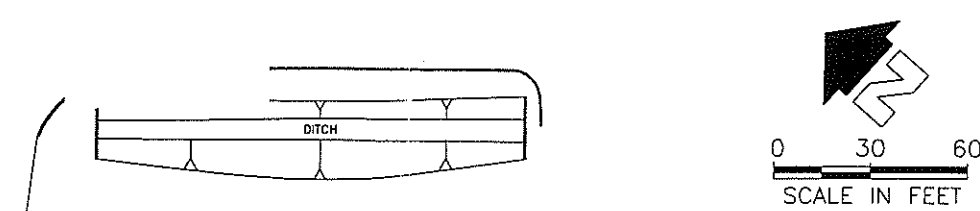


Figure 2-7
GROUNDWATER
GRADIENT AND CONTAMINANT CONCENTRATION MAP
JANUARY 2005
UST SITE 43402, MCB CAMP PENDLETON, CA
SES-TECH

DRAWN BY: MD DATE: 08/19/05	CHECKED BY: MC REV: REVISION 0	APPROVED BY: MC	DCN: SES-TECH-05-0126 CTO: #0004	DRAWING NO: 05012628.DWG
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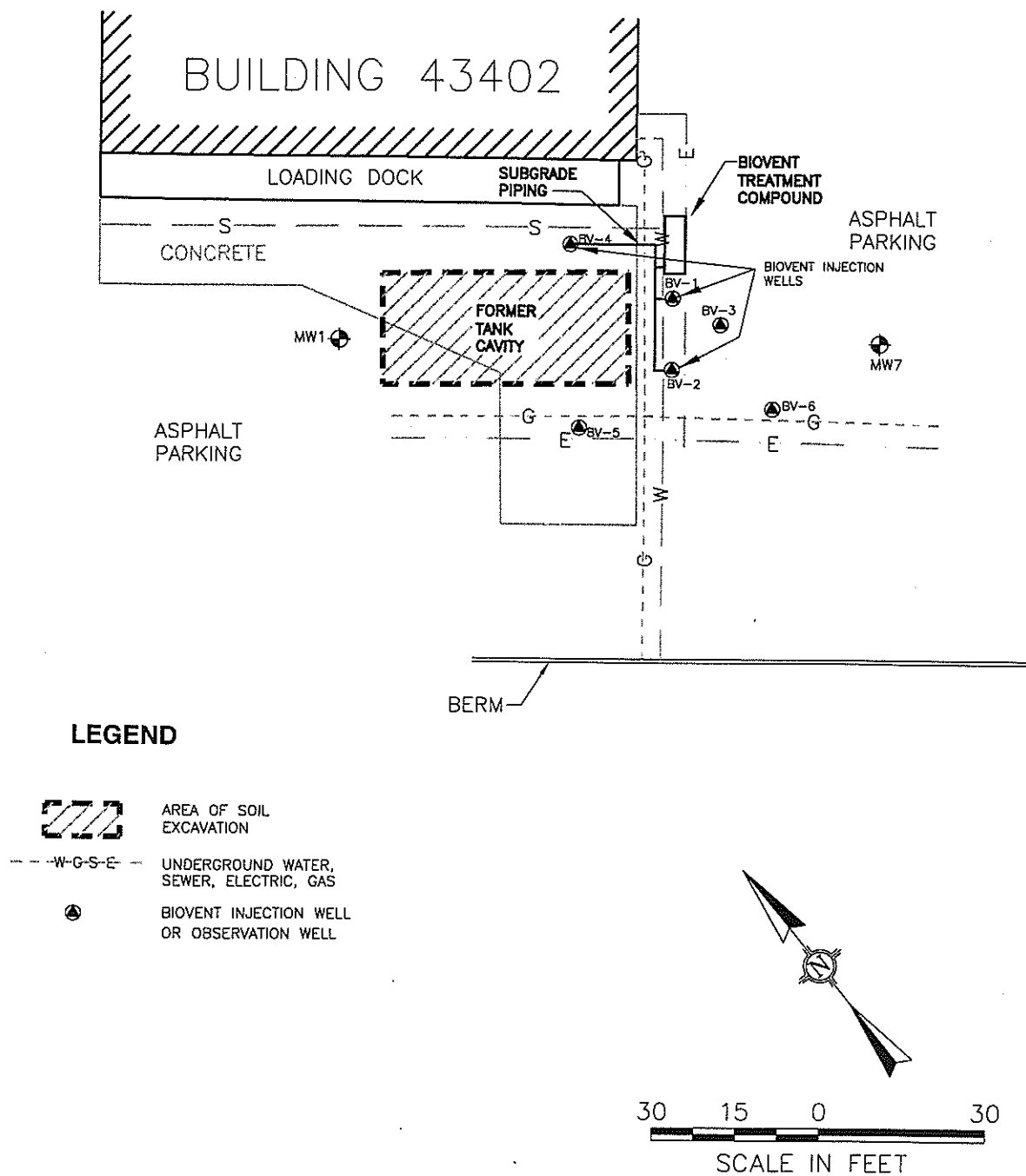


FIGURE 2-9

SUMMARY OF GAS CONCENTRATIONS DURING RESPIRATION
AT BIOVENT INJECTION WELLS, UST SITE 43402

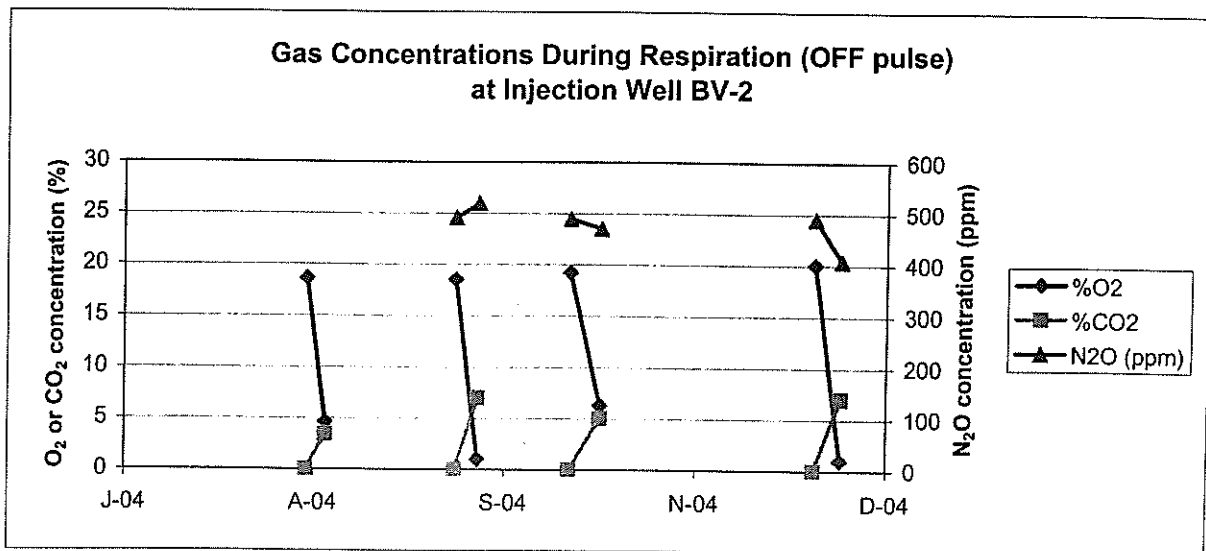
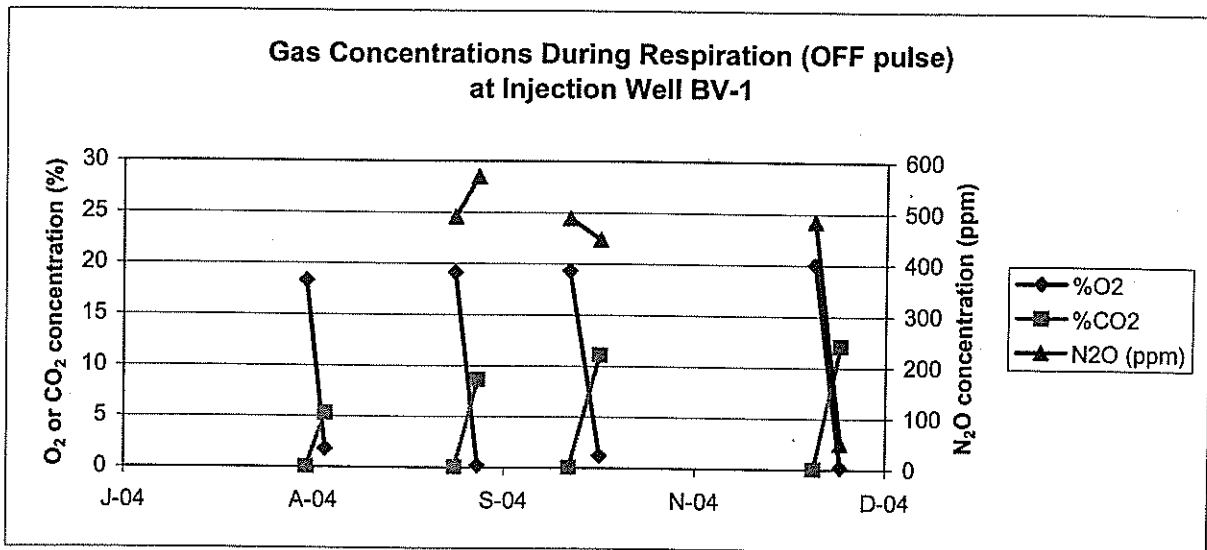
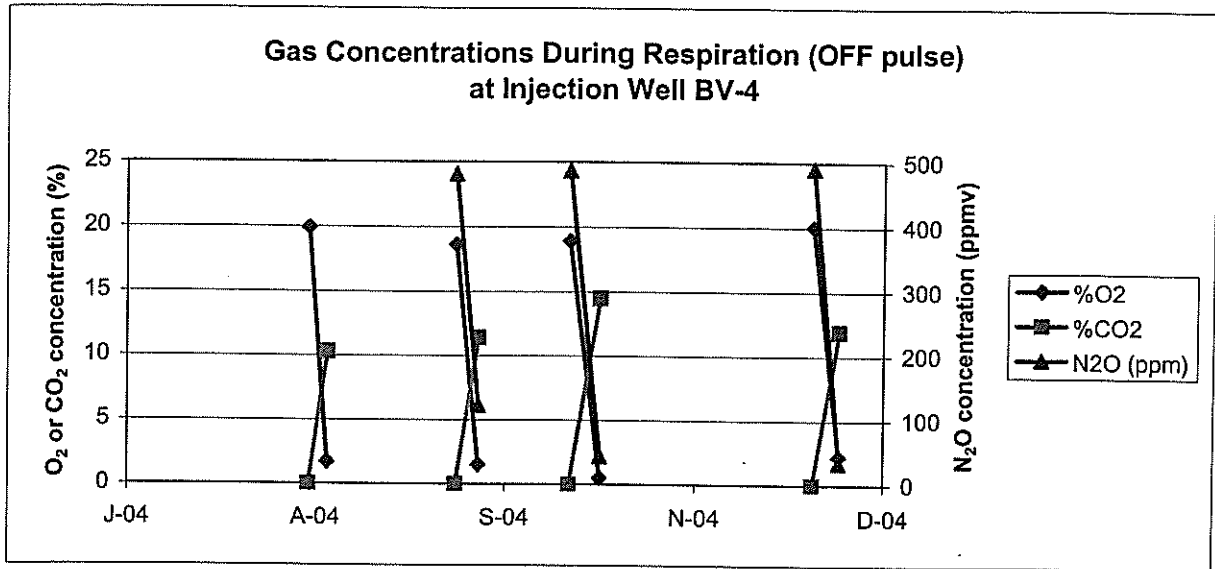
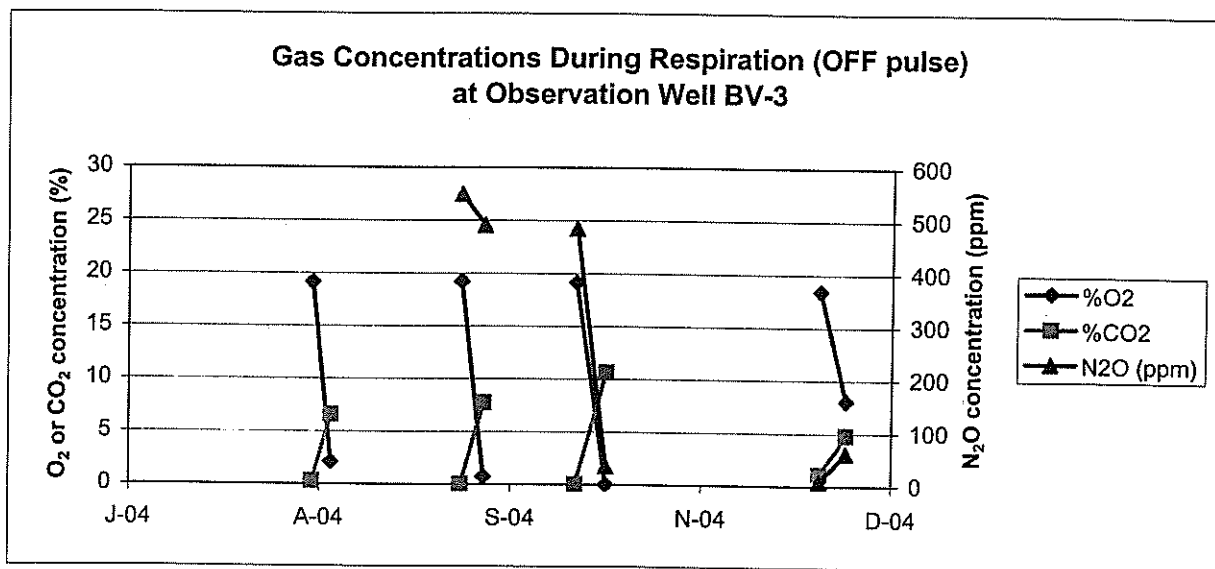
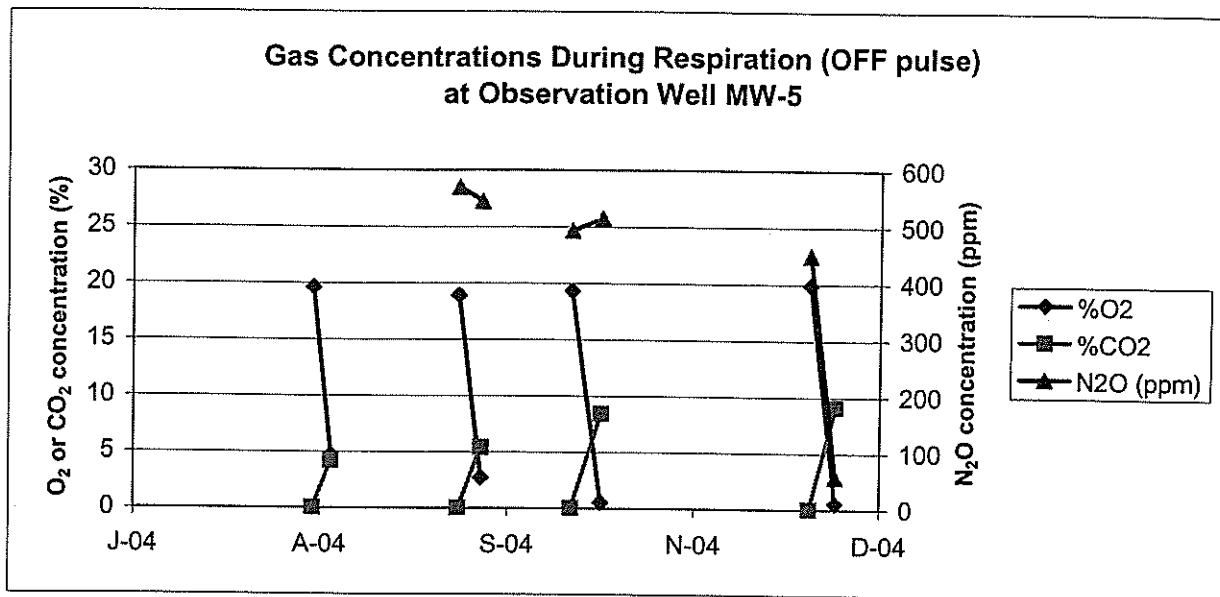
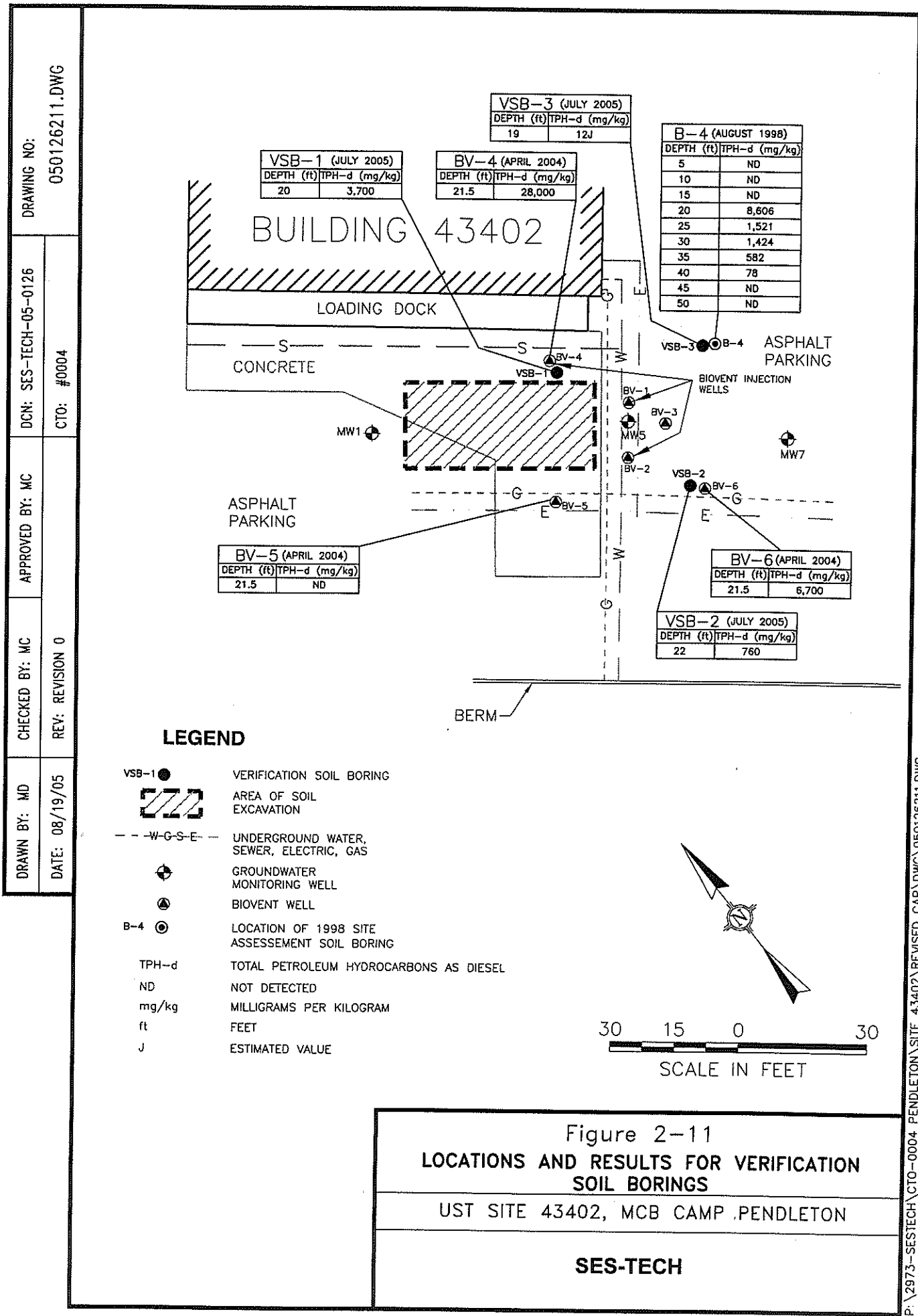


FIGURE 2-10

SUMMARY OF GAS CONCENTRATIONS DURING RESPIRATION
AT BIOVENT OBSERVATION WELLS, UST SITE 43402





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 PLOT/UPDATE: SEP 21 2005 08:28:14

APPENDIX A

BIOVENT PILOT TEST REPORT

**Naval Facilities Engineering Command, Southwest
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, CA 92132-5190**

**CONTRACT NO. N68711-04-D-1104
CTO No. 0004**

APPENDIX A

FINAL

**BIOVENT PILOT TEST REPORT,
UNDERGROUND STORAGE TANK SITE 43402
Revision 1
September 26, 2005**

**MARINE CORPS BASE
CAMP PENDLETON, CALIFORNIA**

DCN: SES-TECH-05-0126

Prepared by:

SES-TECH

**18000 International Boulevard, Suite 1009
SEATTLE, WA 98188**

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ABBREVIATIONS AND ACRONYMS

bgs	below ground surface
CAP	Corrective Action Plan
cm ³	cubic centimeters
CO ₂	carbon dioxide
DO	dissolved oxygen
FWENC	Foster Wheeler Environmental Corporation
hp	horsepower
MCB	Marine Corps Base
mg/kg	milligrams per kilogram
O ₂	oxygen
PID	photoionization detector
PVC	polyvinyl chloride
ROI	radii of influence
scfm	standard cubic feet per minute
STP	standard temperature and pressure
SVMP	soil vapor monitoring probe
TEP	triethyl phosphate
TPH-d	total petroleum hydrocarbons quantified as diesel
TtFW	Tetra Tech FW, Inc.
UST	Underground Storage Tank
VOC	volatile organic compound

1.0 INTRODUCTION

This report documents and evaluates the results of a biovent pilot test conducted at Underground Storage Tank (UST) Site 43402, 43 Area, Marine Corps Base (MCB) Camp Pendleton, California. Due to the presence of impacted soils immediately above groundwater, the potential use of biosparging was also tested. The pilot test was conducted in accordance with the *Final Bioventing/Biosparging Pilot Test Work Plan for UST Site 43402* (FWENC, 2003).

1.1 PILOT TEST OBJECTIVES

The pilot test was conducted at the subject site to primarily evaluate the feasibility of using bioventing as a remediation technology for petroleum hydrocarbon-impacted soils, and to obtain data required for potential future design of a full-scale system. Biosparging was also tested due to the presence of impacted soils immediately above groundwater.

The primary objectives of the tests were as follows:

- Estimate the bioventing radius of influence
- Estimate the potential effectiveness of biosparging at the site
- Estimate biological respiration rates in the subsurface via oxygen (O₂)/carbon dioxide (CO₂) measurement
- Obtain design parameters for potential full-scale implementation
- Evaluate the potential benefit of vapor-phase fertilization of the subsurface

1.2 DOCUMENT ORGANIZATION

This report is organized into the following sections:

- **Section 1.0 - Introduction**—includes background and objectives of the pilot test.
- **Section 2.0 - Field Activities**—includes a summarized description of the pilot test activities performed.
- **Section 3.0 - Data Analyses**—includes the presentation and evaluation of the data collected.
- **Section 4.0 - Conclusions and Recommendations**—presents a summary of the findings, recommendations, and parameters for the design of a full-scale system.
- **Section 5.0 - References**—lists the references cited in this report.

2.0 FIELD ACTIVITIES

This section presents a summary of the associated field activities related to the biovent pilot test that was conducted at UST Site 43402.

2.1 BIOVENT WELL INSTALLATION

Three multi-screened biovent wells (BV-1 to BV-3) were initially constructed for the pilot test. Locations of the wells are shown on Figure 2-8 in the Corrective Action Plan (CAP). Each well consisted of 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) casing in a double-nested configuration with screened intervals at approximately 20 to 25 feet below ground surface (bgs) and 28 to 30 feet bgs. A screen slot size of 0.010 inches was used for the screened intervals. In addition, each well contained two soil vapor monitoring probes (SVMPs). The SVMPs consisted of ½-inch-diameter Schedule 40 PVC with ½-inch-diameter Schedule 40 PVC screen at approximately 10 feet bgs and 15 feet bgs.

2.2 CONVEYANCE PIPING INSTALLATION

The biovent injection wells (BV-1 and BV-2) were connected via aboveground flexible hose to the blower. The exerted pressures on the biovent system did not exceed 5 pounds per square inch, which was well within the tolerances of the piping and other system components.

2.3 PILOT TEST EQUIPMENT

The pilot test equipment consisted of a skid-mounted blower package to inject atmospheric air into the biovent wells.

Individual components included:

- A 5-horsepower (hp) positive-displacement blower. The blower was rated for a maximum flow of 25 standard cubic feet per minute (scfm).
- Associated piping, instruments, gauges, and valves.
- Extraction flow was measured using an in-line flow meter, pressures were measured using Magnehelic gauges, oxygen and carbon dioxide were measured using a gas analyzer, and dissolved oxygen (DO) concentrations were measured using a DO meter.

2.3.1 Biosparging Pilot Test

The potential use of biosparging was tested, which consisted of simultaneous air injection into the lower screens of wells BV-1 and BV-2 to determine if oxygenation of the surrounding groundwater could be achieved. Helium gas was bled into the air injection stream for use as a tracer. Monitoring of groundwater DO levels, helium in the headspace of well BV-3, and

pressure monitoring and respiratory gas (oxygen and carbon dioxide) monitoring in the headspace of all wells and vapor probes was conducted. The duration of the sparging test was approximately 7 days.

The sparging system operating parameters and observation data are shown in Table 2-1.

2.3.2 Respirometry Testing

Respirometry testing was conducted to assess aerobic biological activity in the vadose zone. In the chemical reaction for aerobic respiration, oxygen is a reactant and carbon dioxide is an end-product. Oxygen depletion, coupled with carbon dioxide production, indicates aerobic biological activity. Oxygen gas and carbon dioxide gas concentrations were monitored after oxygenation of the vadose zone at BV-1, BV-2, and BV-3. Three respirometry tests were conducted, each after a period of air injection. The field data for the Respirometry Tests I, II, and III are shown in Table 2-2, Table 2-3, and Table 2-4, respectively.

2.3.3 Bioventing Short-term Pilot Test

A two-part short-term bioventing test was conducted using wells BV-1 and BV-2. For the first part of the test, air was injected into each well individually at 5 scfm for several hours to calculate pressure-based radii of influence. The injection pressure at the biovent wells and pressure reading data at observation points for both injections are shown in Table 2-5 and Table 2-6.

For the second part of the test, air was injected at 6 scfm simultaneously into BV-1 and BV-2 for a 10-day period (November 24, 2003 to December 3, 2003) to assess respiratory gas levels and volatile organic compound (VOC) concentrations in the injection field. This period of injection was the oxygenation phase of Respirometry Test III. During the injection period, oxygen, carbon dioxide, and photoionization detector (PID) levels were measured at proximal and distal groundwater monitoring wells and at the vapor probes. The data for the second part of the short-term test are shown in Table 2-4.

2.3.4 Bioventing Extended Pilot Test

A 4-month extended bioventing test was conducted after the short-term tests. The test parameters were identical to the second part of the short-term test – simultaneous injection into BV-1 and BV-2 at 6 scfm; however, air was injected on a pulsed basis. The pulsing scheduling was 7 days of air injection, followed by 4 days of system inactivation. Respiratory gases were measured one time per pulsing cycle at the fourth day of system activation.

The data are shown in Table 2-7.

3.0 DATA ANALYSES

Field data obtained during the pilot tests were used to evaluate the feasibility of biosparging/bioventing for remediation of total petroleum hydrocarbons quantified as diesel (TPH-d)-impacted subsurface soils. This section presents summaries of the data and data analyses.

3.1 BIOSPARGING TEST

The biosparging monitoring data indicate that the groundwater in the vicinity cannot be effectively oxygenated. The DO level at groundwater monitoring well MW-5, located approximately 4 feet away from BV-1, did not increase for the duration of the test. Refer to Figure 3-1 for DO levels at MW-5 as a function of time. The DO level also did not increase at observation well BV-3. Thus, the injected air exits the groundwater in the immediate vicinity of the sparge well into the vadose zone, suggesting that the site is not suitable for a groundwater biosparging system.

3.2 RESPIROMETRY TESTS

Three respirometry tests were conducted during the pilot test for assessment of aerobic biological activity.

3.2.1 Respirometry Test I

Despite the unsuccessful sparging results for groundwater, the fortuitous oxygenation of the vadose zone allowed for the performance of a vadose-zone respirometry test. After full atmospheric oxygenation was observed at monitoring well MW-5, bioventing wells BV-1, BV-2, and BV-3, and the vapor probes, the system was turned off and respiratory gas concentrations were then measured every 1 to 2 days.

In general, oxygen levels declined and carbon dioxide levels increased. Linear regression analyses on the oxygen data were performed to measure oxygen use rates and to determine what degree of the observed oxygen use was due to biological respiration, assuming zero-order reaction kinetics. Gaseous diffusive exchange between the oxygenated air introduced by the biosparging system and the subsurface ambient oxygen-poor air will occur and should be subtracted out when measuring respiration rates. Oxygen use rates (k values in units of percent/day) were calculated at the bioventing wells, MW-5, and the six monitoring probes. Because the probes are not in hydrocarbon-affected soils, these probes are control probes that roughly measure gaseous diffusion. The bioventing wells and MW-5, which are in hydrocarbon affected soils, measure respiration and gaseous diffusion. Therefore, in theory, if respiration is occurring, k values at the biovent wells and MW-5 should be higher than at the soil probes. The data generally follow the theory:

The average k value at the bioventing wells and MW-5 is -1.08 percent/day. The average k value at the soil probes is -0.54 percent/day. Subtracting out the "diffusion" k from the total k, a "respiration" k of -0.54 percent/day is obtained. This is an indication that the system is enhancing aerobic degradation at the site and also represents a performance parameter that can be tracked over the lifecycle of the system at full scale. Field data are presented graphically in Figure 3-1; the results of the regression analyses are shown in Table 3-1.

3.2.2 . Respirometry Test II

A second test was conducted to verify the results from the first respirometry test. The biosparge system was turned on to reoxygenate the vadose zone to atmospheric conditions, and then was shut off again.

The regression showed a higher oxygen use rate for the second test. A "respiration" k value of -4.7 percent day⁻¹ was obtained. This increased k value due to respiration, most likely, is the result of higher microbial populations that may have been produced during the course of the testing. With a steady availability of oxygen, more robust populations of microbes initially would be expected and would result in higher oxygen use rates. Thus, this second test is confirmation that aerobic degradation is occurring at this site. Field data are presented graphically in Figure 3-2; the results of the regression analyses are shown in Table 3-2.

3.2.3 Respirometry Test III

A third respirometry test was conducted to determine the pulsing frequency and duration at full scale. A pulsed injection is preferred over a constant injection to prevent the potential lateral migration of any volatile organics. Refer to Table 3-3 and Figure 3-3 for the regression analyses.

Full oxygenation was observed at the bioventing wells within 7 days. Oxygen levels were depleted within 5 days. Based on this respirometry test, an effective pulsing schedule would be a 7-day pulse of oxygenation at 6 scfm with 4 days between pulses.

3.3 BIOVENT TEST

3.3.1 Short-term Test

Data from Part I of the biovent test indicated the calculated radii of influence (ROI) were 42 feet for BV-1 and 38 feet for BV-2. ROI values were calculated by performing a linear regression on a plot of the absolute pressure squared versus the natural logarithm of the radial distance, with the ROI defined as the distance at which the pressure declines to 0.1 inches of water (refer to Tables 2-6 and 2-7 for the inputs and outputs of the ROI calculations).

During the Part 2 testing period, oxygen, carbon dioxide, and PID levels were measured at proximal and distal groundwater monitoring wells and at the vapor probes. The respiratory gas

levels were measured to verify the ROI calculations from the Part I bioventing data. The PID readings were used to determine if excessive air injection causes potential migration of volatile organics (Table 2-4).

PID readings at BV-3 and MW-5, a proximal groundwater monitoring well, did not increase from baseline levels as oxygenation proceeded. Additionally, low readings at the vapor probes and MW-1, a distal groundwater monitoring well were observed for the duration of the oxygenation period. Refer to Figure 3-4 for a graph of the VOC-concentration-oxygen correlation. This data distribution indicates that, as air is injected into the subsurface at low-flow rates, there was no significant mobilization of organic compounds into soil vapor, and no significant migration of volatile organics upward to ground surface nor laterally. The soil beneath this site is ideal suited for the application of bioventing under low-flow conditions.

3.3.2 Extended Test

During the 4-month extended biovent test, the pulsing cycle was approximately 7 days of injection, followed by approximately 4 days of system inactivation. Respiratory gas concentrations were collected on the last day of system inactivation for each pulsing cycle to monitor system performance. Using these data, carbon dioxide production rates and oxygen use rates for each pulsing cycle at each well (BV-1, BV-2, BV-3, MW-5) were calculated.

The carbon dioxide production rate and oxygen use rates were calculated as followed:

- It was assumed that the carbon dioxide percent volume concentration and the oxygen percent volume concentration were 0 percent and 20 percent, respectively, after the last day (generally the seventh day) of the injection.
- The carbon dioxide concentration measured on the last day (generally the fourth day) of system inactivation was divided by the number of days of system inactivation (generally 4 days) to yield the carbon dioxide production rate for that cycle.
- The oxygen concentration measured on the last day (generally the fourth day) of system inactivation was subtracted from 20 percent and the result was divided by the number of days of system inactivation (generally 4 days) to yield the oxygen use rate for that cycle.

Figures 3-5 and 3-6 show the carbon dioxide production rate and oxygen utilization rate with successive cycles of system operation.

Linear regression lines were plotted for both parameters for each well to analyze parameter trend. The regressions on the carbon dioxide production rate data show a general decrease in carbon dioxide production rates with time for all wells monitored. Similarly, the regressions on the oxygen use rate data show a general decrease in oxygen use rates with time for all wells monitored.

These trends can be interpreted potentially in one of two likely explanations:

- Either, carbon dioxide production rates and oxygen use rates are decreasing due to declining concentrations of diesel hydrocarbons; or
- Carbon dioxide production rates and oxygen use rates are decreasing due to declining concentrations of available nutrients, namely, nitrogen

To determine which scenario is more likely, the stoichiometry of aerobic biodegradation of petroleum hydrocarbons to determine the nitrogen requirement was analyzed (see next section).

3.4 FULL-SCALE DESIGN

Full-scale design parameters are detailed in the following sections.

3.4.1 Stoichiometry

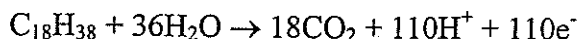
Stoichiometry is useful in the design and operation of a bioventing system. For example, the amount of nitrogen required, the quantity of biosolids produced, and the amount of oxygen required in an aerobic process can be calculated from the stoichiometric equation.

Oxidation-reduction reactions entail the transfer of electrons. In biological treatment processes, the organic pollutant is typically the electron donor. Both the organism energy requirement and the organism synthesis receive the electrons as the acceptors. Oxygen is the electron acceptor for the energy requirement; and either nitrate or ammonia is the nitrogen source in the organism synthesis.

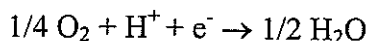
Assumptions:

- 18-chain alkane ($C_{18}H_{38}$) is representative of residual diesel fuel in soil
- nitrate is predominant source of nitrogen
- fs (fraction of electrons used for cell synthesis) = 0.39
- fe (fraction of electrons used for energy) = 0.61

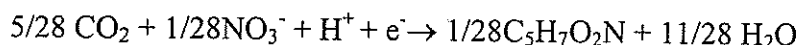
Electron donor half-reaction (Rd):



Electron acceptor half-reaction (Ra):



Cell-synthesis half-reaction (Rc):

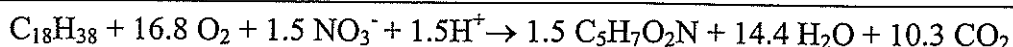


Normalizing Rd to one electron: $0.009\text{C}_{18}\text{H}_{38} + 0.327\text{H}_2\text{O} \rightarrow 0.164\text{CO}_2 + \text{H}^+ + \text{e}^-$

fe x Ra: $0.152\text{O}_2 + 0.61\text{H}^+ + 0.61\text{e}^- \rightarrow 0.305 \text{H}_2\text{O}$

fs x Rc: $0.696 \text{CO}_2 + 0.014 \text{NO}_3^- + 0.404\text{H}^+ + 0.39\text{e}^- \rightarrow 0.0139 \text{C}_5\text{H}_7\text{O}_2\text{N} + 0.153\text{H}_2\text{O}$

The aforementioned three equations are summed up, which yields the net reaction for biodegradation of diesel:



From the net reaction, the following ratios are obtained:

- Alkane/O₂ molar ratio: $1/16.8 = 0.06$
- Alkane/CO₂ molar ratio: $1/10.3 = 0.097$
- Alkane/ NO₃⁻ molar ratio: $1/1.5 = 0.65$
- Alkane/N mass ratio: (Alkane/ NO₃⁻ molar ratio) x MW_{alkane}/MW_{nitrogen} = 11.8

Using these molar/mass ratios and site-specific data, it can be determined if the site requires nutrient addition to adequately remediate TPH-d via biodegradation.

3.4.2 Nitrogen Requirement

The nitrogen requirement is approximated as the maximum encountered hydrocarbon concentration divided by the alkane/N mass ratio. Analytical laboratory data indicated a diesel concentration of 11,000 milligrams per kilogram (mg/kg) and a nitrogen (as nitrate) concentration of 8.6 mg/kg are present at the site. Thus:

$$\begin{aligned}\text{N requirement} &= \text{diesel concentration/Alkane/N mass ratio} = 11,000 \text{ mg-diesel/kg} / 11.8 \\ &= 930 \text{ mg-N/kg}\end{aligned}$$

The stoichiometric nitrogen requirement exceeds the nitrogen (as nitrate) available at the site:

$$930 \text{ mg-N/kg nitrogen requirement} > 8.6 \text{ mg-N(as nitrate)/kg available at site}$$

Therefore, the site requires nutrient addition, along with oxygen, to adequately biodegrade residual diesel in site soils.

3.4.3 Nutrient Test

Since stoichiometric calculations indicated that subsurface nutrients would be a limiting factor in biodegradation of diesel at the site, additional testing was conducted to determine if vapor-phase fertilization of the soil could be achieved with the bioventing system. On April 20, 2004, six new soil vapor probes were installed in three locations (BV-4, BV-5 and BV-6) (two probes per location) with screened intervals at 15 feet bgs and 20 feet bgs at radial distances between 20 and 25 feet from bioventing wells BV-1 and BV-2 (See Figure 2-8 in the CAP). Soil samples were collected and analyzed for orthophosphate, nitrogen as nitrate and ammonia, TPH-d, and hydrocarbon degraders (microbes). The analytical results are presented in Table 3-4. The details of this installation are described in the addendum to the *Addendum to the Final Biosparge/Biovent Pilot Test Work Plan for Underground Storage Tank Site 43402*, dated March 16, 2004 (TtFW, 2004). Refer to Attachments 1 and 2 for boring logs and laboratory analytical reports.

At probe BV-4, the maximum diesel concentration was 28,000 mg/kg and the total nitrate concentration (sum of nitrogen as nitrate and ammonia) was 20.6 mg/kg. The diesel to nitrate ratio for boring BV-4 is approximately 1360. For boring BV-5, the diesel concentration was 6,700 mg/kg and the total nitrate concentration was 32.2 mg/kg. The diesel to nitrate ratio for boring BV-5 is approximately 208. The stoichiometric ratio of diesel to nitrate is approximately 11.8 by mass. Ratios exceeding 11.8 indicates nitrogen deficiency. Thus, along with stoichiometric calculations, analytical results suggest that the soil is significantly deficient in nitrogen.

Based on the results of stoichiometric calculations, the extended bioventing pilot test, and the soil analytical results from the probe installation, fertilizer (nutrients) will be required to support the biodegradation of hydrocarbons in the vadose zone at the site. Nitrogen is essential for cell building and is required in the greatest amounts compared to other nutrients. Phosphorus is also necessary, but in lower quantities than nitrogen. Therefore, an air injection with vapor-phase nutrient amendment test was conducted to determine if nutrients could be effectively distributed in the vadose zone.

Nitrous oxide, a gas at standard temperature and pressure (STP), was bled into the air injection stream downstream of the blower. Triethyl phosphate (TEP), a liquid at STP, was poured into a 55-gallon vessel that was placed in-line. The process stream was bubbled into the vessel to vaporize the TEP into the injection air stream.

To determine the nitrous oxide injection rate that is required at the air injection rate of 6 scfm, the following calculations were performed:

% N₂O required in air stream =

$$\begin{aligned} &= (\text{stoichiometric ratio of nitrate to oxygen}) \times (\text{moles N}_2\text{O per moles NO}_3^-) \times (\% \text{ oxygen in air}) \\ &= (1.5 \text{ moles nitrate} / 16.8 \text{ moles oxygen}) \times (0.5 \text{ mole N}_2\text{O per 1 mole NO}_3^-) \times (20\% \text{ oxygen}) \\ &= 0.9\% \text{ N}_2\text{O required in air stream} \end{aligned}$$

injection rate of N₂O = % N₂O required in air stream x injection rate of air stream / 100

$$\begin{aligned} &= 0.9\% \text{ N}_2\text{O} \times 6 \text{ scfm} \times 60 \text{ mins/hr} / 100 \\ &= 3.2 \text{ cubic feet per hour of N}_2\text{O} \end{aligned}$$

Phosphorus is only required in trace amounts stoichiometrically, and therefore, does not appear in the stoichiometric equations. As a result, phosphorus does not need to be added at a rate greater than 10 percent of the nitrogen injection rate.

To estimate the phosphorus injection rate, the following calculation is performed:

TEP injection rate =

$$\begin{aligned} &= (\text{N}_2\text{O gas injection rate}) \times (\text{mole of gas} / 0.9 \text{ cubic feet}) \times (\text{molecular wt of TEP}) \times \\ &\quad (0.1 \text{ mole TEP} / \text{mole N}_2\text{O}) / (\text{specific weight of water} \times \text{specific gravity of TEP}) \\ &= (3.2 \text{ cubic feet/hour}) \times (1 \text{ mole} / 0.9 \text{ cubic feet}) \times (182.2 \text{ g/mole}) \times (0.1 \text{ mole/mole}) / \\ &\quad 1.06 \text{ g/cm}^3 \\ &= 61 \text{ cm}^3\text{-liquid-phase TEP per hour} \end{aligned}$$

Therefore, in summary, for the nutrient addition test, air was injected at 6 scfm; nitrous oxide was injected at 3.2 cubic feet per hour; and it was attempted to inject TEP at approximately 61 cubic centimeters (cm³) of liquid per hour.

Prior to injection, vapor samples were collected at the new probe locations (BV-4, BV-5, and BV-6) and BV-3 and were analyzed for the presence of nitrous oxide (by field instrument) and TEP (by laboratory analysis) as baseline measurements. Then, the injection was commenced according to the calculated injection rates for air, nitrous oxide, and TEP on the planned pulsing cycle of 7 days ON and 4 days OFF for two cycles.

Performance data collection included the measurement of oxygen, carbon dioxide, nitrous oxide, and TEP concentrations at injection wells and observation points screened in the vadose zone.

Cycle 1 Results

The highlights of Cycle 1 are as follows:

- Breakthrough of atmospheric oxygen conditions occurred at MW5, BV-3, and BV-6 by Day 2 of the ON pulse.
- Breakthrough of atmospheric oxygen conditions did not occur at BV-4 or BV-5 for the first 7 days of the ON pulse. The pulse was continued an additional 3 days, but still no breakthrough occurred. During the pulse, no appreciable rise in oxygen was observed in either probe location.
- Breakthrough of nitrous oxide occurred at all observation points, including BV-4 and BV-5 by Day 2 of the ON pulse.
- Pressure readings indicated that all three of the new probe locations are within the radius of bioventing influence.
- TEP volatilization was negligible during the ON pulse.
- Respirometry testing conducted during the OFF pulse showed respiration at all oxygenated wells and probes.

Refer to Table 3-5 for the field data.

The appearance of nitrous oxide in BV-4 and BV-5 indicated that the probe locations are within the bioventing area of influence. However, the lack of appearance of oxygen at the same probe locations may suggest that the oxygen is being biologically used faster than it is being delivered at the "edge" of the area of influence. Therefore, for Cycle 2, the air injection rate was increased from 5 scfm to between 15 and 20 scfm to determine if excess oxygen can be delivered to BV-4 and BV-5.

Additionally, the TEP delivery apparatus was modified to increase the air/TEP contact area. With this modification and the increased injection rate, higher volatilization rates of TEP should be observed.

Nitrous oxide was not injected during Cycle 2, since distribution of the gas in the vadose zone was already demonstrated during Cycle 1.

Cycle 2 Results

The highlights of Cycle 2 are as follows:

- The higher flow rate led to atmospheric breakthrough at BV-5 by Day 6 of the ON pulse.
- BV-4 showed no indication of oxygenation by Day 9 of the ON pulse.

- TEP volatilization/injection rate was measured using the level indicator of the nutrient vessel. The TEP level decreased approximately 0.3 inches in 3 days, with the vessel filled approximately $\frac{1}{8}$ of its total volume with TEP. Based on the dimensions of the 55-gallon drum (diameter of 24 inches), the TEP volatilization/injection rate was calculated to be cm^3 per hour.
- Due to the rapid degradation of TEP that was experienced under laboratory conditions, direct measurement of TEP in the collected vapor samples was not possible. Therefore, by-product quantification was performed as an indicator of TEP presence in the vapor samples. Apparently, ethanol is a major by-product of TEP degradation.
- Ethanol was detected in trace amounts in the system influent stream, but generally not detected at any of the new probe locations.

Refer to Table 3-5 for the field data for Cycle 2. Laboratory data for ethanol are tabulated in Table 3-6.

Despite the higher injection rate, atmospheric breakthrough could not be achieved at BV-4. It would appear that this probe cannot be adequately oxygenated by injection exclusively through wells BV-1 and BV-2 with the current blower at the site. Increasing the injection flow rate to an even higher flow rate by an upgrade of the blower without concurrent extraction of the soil vapor is not recommended. Reasonably low-flow conditions for injection must be maintained since no extraction wells exist in the current bioventing configuration.

The absence of ethanol at BV-4, BV-5, and BV-6 indicates the lack of distribution of TEP to the diesel-affected soils with the current injection well field. Further, TEP could not be injected at the target rate of 61 cm^3 per hour.

The conclusions of the nutrient test are as follows:

- Nitrous oxide could be effectively distributed to outlying probe locations, but oxygen and TEP could not be. Therefore, at least one additional injection well is recommended to sufficiently oxygenate and fertilize the diesel-affected soils
- TEP was injected at a rate of approximately 31 cm^3 per hour, which was below the target rate of 61 cm^3 per hour. Therefore, the TEP level in the nutrient vessel should be raised by adding additional TEP, which will increase the air/TEP contact time, thereby, increasing the volatilization rate.

3.4.4 Equipment and Apparatus for Potential Full-scale Implementation

Wellfield

Based on results of the nutrient test, the current well field should be expanded for sufficient oxygenation of the vadose zone. Simultaneous air injection at bioventing wells BV-1 and BV-2, and at BV-4 is recommended at full scale.

Nutrient Addition

A limited mass of nutrients will be added to the vadose zone as demonstrated in the nutrient test. There will be no percolation of nutrients into the groundwater since the nutrients will be delivered in the vapor phase. Because of the limited quantity of vapor-phase fertilizer that will be added and because of the stoichiometric/kinetic control of its delivery, the nutrients introduced into the subsurface will be absorbed and used in the vadose zone only, and thus, will not result in a discharge to groundwater. Fertilization of the vadose zone at full scale will not have significant impact to regional groundwater quality.

Operating Parameters

During potential full-scale operation, air will be injected at 6 scfm; nitrous oxide will be injected at 3.2 cubic feet per hour; and TEP will be injected at a target rate of 61 cm³ of liquid per hour. Additionally, the pulsing cycle will be 7 days ON and 4 days OFF.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the biosparging, bioventing, and nutrient addition pilot tests, the following conclusions can be made:

1. The biosparging test indicated that the groundwater could not be effectively oxygenated, likely due to the low permeability soils in the saturated zone.
2. The short-term bioventing test indicated that the vadose zone can be effectively oxygenated.
3. The respirometry testing indicated that oxygenation of the vadose zone at approximately 20 to 25 feet bgs stimulates biological activity.
4. Stoichiometric analysis showed that the site is nitrogen-deficient for supporting complete biodegradation of the diesel-affected soil.
5. Carbon dioxide production rate regressions and oxygen use rate regressions also suggest that nutrient addition will be beneficial during bioventing.
6. Nutrient testing showed that nitrous oxide could be completely distributed effectively in the vadose zone, but not oxygen or TEP with the current injection well field (BV-1 and BV-2).
7. Oxygenation and vapor-phase fertilization of the diesel-affected soils using an expanded injection well field should be performed to address nutrient and oxygen deficiency of the entire impacted vadose zone.
8. Full-scale operation of a bioventing system with nutrient-addition apparatus is recommended to remediate the diesel-affected soils using existing injection wells BV-1 and BV-2 and one additional injection well at BV-4.

5.0 REFERENCES

- Foster Wheeler Environmental Corporation (FWENC). 2000. *Final Bioventing/Biosparging Pilot Test Work Plan for USG 43402*. Marine Corps Base, Camp Pendleton, California.
- Tetra Tech FW, 2004. *Addendum to the Final Biosparge/Biovent Pilot Test Work Plan for Underground Storage Tank Site 43402*. March 16.

TABLES

TABLE 2-1

SPARGING OPERATING PARAMETER AND OBSERVATION DATA

Date	Well	Sparge Parameters			BS-2		BS-3		MW-5	
		Pressure (psig)	Flow (scfm)	Helium Injection (%volume)	DO (mg/L)	Helium (ppm)	DO (mg/L)	Helium (ppm)	DO (mg/L)	Helium (ppm)
10/7/2003	BS-1	3.8	4	5	0.06	0.32	0.03	0.05	0.07	2
10/8/2003	BS-1	2.4	2	2	0.09	0	0.08	0.55	0.22	0.7
10/10/2003	BS-1	2.4	3	2	0.02	0	0.07	0.1	0.2	2.4
10/13/2003	BS-1	2.4	3	2	0.08	0.09	0.03	0.2	0.1	2
10/14/2003	BS-1 and BS-2	2.4	6	2	-	-	0.15	0.68	0.24	0.32
10/15/2003	BS-1 and BS-2	2.2	6	2	-	-	0.03	0.73	0.13	0.6
10/17/2003	BS-1 and BS-2	2.2	6	2	-	-	0.04	0.15	0.1	1.2

Notes:

DO - dissolved oxygen

mg/L - milligrams per liter

ppm - parts per million

psig - pounds per square inch, gauge

scfm - standard cubic feet per minute

TABLE 2-2
RESPIROMETRY TEST I DATA

	BV-1		BV-2		BV-3		MW-5		SP-1		SP-2		SP-3		SP-4		SP-5		SP-6	
Date	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)
10/8/2003	7.4	7.5	2.3	9.5	2.3	10.1	2	9.8	na	na	na	na	na	na	na	na	na	na	na	na
10/9/2003	19.4	0.2	0.1	9.1	3.4	6.7	18.6	0.3	na	na	na	na	na	na	na	na	na	na	na	na
10/10/2003	19.4	0.1	0	8.6	3.9	5.9	18.9	0.3	na	na	na	na	na	na	na	na	na	na	na	na
10/13/2003	20.1	0	17.2	0.3	18.3	0.3	20.6	0.1	na	na	na	na	na	na	na	na	na	na	na	na
10/14/2003	20.4	0	17.9	0.3	18.9	0.3	20.3	0.1	na	na	na	na	na	na	na	na	na	na	na	na
10/15/2003	20.5	0	19.8	0.2	19.5	0.2	20.5	0	na	na	na	na	na	na	na	na	na	na	na	na
10/17/2003	19.9	0	19.7	0.2	18.9	0.2	19.9	0	16.9	4.2	19.7	0.2	20.3	0	20.9	0	9.1	3.6	16.9	0.9
10/20/2003	17.5	0.3	16.5	0.2	10.4	1.1	11.7	1.1	13.5	0.6	16.5	3.4	16	0.7	20.3	0	9.2	4.7	15.1	1.8
10/24/2003	9.6	1.3	12.5	0.8	10.7	2.2	10.6	1.6	11.3	2	18.7	2.2	20	0	14.5	2	13.3	1.4	14.1	2.9
10/29/2003	5.7	3.3	8.1	1.7	4.2	4.2	6	4	8	2.6	11.5	5.3	11.4	1.4	9.2	3.5	11	2	14.2	2.7
11/3/2003	0.2	8.8	0.8	4.8	0	7.4	0.2	8.9	1.2	6.4	19	2.1	3.7	2.1	5.3	3.5	10.2	3.1	11.8	4.3
																	0	6	10.6	4.7

Notes:

na - not analyzed
CO₂ - carbon dioxide
O₂ - oxygen

TABLE 2-3
RESPIROMETRY TEST II DATA

Date	BV-1		BV-2		BV-3		MW-5		SP-1		SP-2		SP-3		SP-4		SP-5		SP-6	
	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)
11/3/2003	0.2	8.8	0.8	4.8	0	7.4	0.2	8.9	1.2	6.4	19	2.1	3.7	2.1	5.3	3.5	0	6	10.6	4.7
11/4/2003	20.2	0.1	20	0.3	18.6	1.3	20.3	0.1	18.4	1.9	12.8	4.1	12.4	4.4	4.7	3.9	10.2	6.9	10.6	4.3
11/6/2003	20.2	0.1	20	0.1	19.2	0.7	20.7	0	19.2	0.9	12.8	4.5	17.2	1.8	14.7	2.9	13.4	5.4	9.9	4.4
11/10/2003	20.5	0	20.1	0.1	19.1	0.7	20.7	0	19.7	0.6	12.4	5.4	17	1.8	16.9	3.1	15.4	3.9	12.5	4.3
11/11/2003	11.9	0.9	15.9	0.7	14.2	1.4	15.9	1	15.6	1.1	15.2	4.4	17.5	1.1	16.3	3.2	15	3.5	12.7	4.3
11/13/2003	1.4	3.4	6	1.8	3.6	3.4	1	4	7.7	1.9	13.2	5.8	20.3	0	10.5	3.3	10.5	4.2	14.3	3.7

Notes:
CO₂ - carbon dioxide
O₂ - oxygen

TABLE 2-4
RESPIROMETRY TEST III DATA

	BV-1			BV-2			BV-3			MW-5			SP-1			
Date	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)
11/17/2003	0.2	6.3	na	0.1	4.1	na	0.4	5.5	240	0.4	6.2	125	3.6	3.7	31	8.7
11/24/2003	20.7	0	na	20.7	0	na	19	0.8	187	20.7	0	140	20.7	0	6	6.8
12/3/2003	20.6	0	na	20.8	0	na	19.4	0.6	159	20.6	0	130	20	0.2	8	15.8
12/5/2003	4.5	2	na	14.2	0.2	na	13.2	1.6	na	7.6	2.7	na	11.2	1	na	14.5
12/8/2003	0.2	6.7	na	2.5	2.6	na	0.2	5.5	na	0.4	6.3	na	7.7	2.1	na	12

Notes:CO₂ - carbon dioxide

na - not analyzed

O₂ - oxygen

PID - photoionization detector

ppm - parts per million

TABLE 2-4

RESPIROMETRY TEST III DATA

SP-2			SP-3			SP-4			SP-5			SP-6			MW-1		
Date	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)	O ₂ (%volume)	CO ₂ (%volume)	PID (ppm)
11/17/2003	6.4	5	13.1	0.9	23	3.8	4.2	8	4.3	4.4	10	12.5	4	5	4.9	7.8	1
11/24/2003	7.2	5	19.3	0.3	4	20.5	0.2	3	16.3	3.6	16	11.8	3.9	11	6.1	4.6	5
12/3/2003	4.4	5	19.7	0.3	1	20.7	0	1	17.4	2.3	17	18	2.3	14	6.2	6	8
12/5/2003	5.5	na	18.5	0	na	20.3	0.1	na	14.7	2.9	na	16.4	3.3	na	na	na	na
12/8/2003	6	na	14.7	0.6	na	15.7	0.7	na	12	2.2	na	16.8	2.5	na	na	na	na

Notes:

CO₂ - carbon dioxide

na - not analyzed

O₂ - oxygen

PID - photoionization detector

ppm - parts per million

TABLE 2-5

SHORT-TERM BIOVENTING TEST DATA FOR INJECTION WELL BV-1

Observation Point	r, distance (feet)	P, vacuum ("H ₂ O)	P, vacuum (psia)	ln r	P ²	Regression
	0.16666	8.20	14.40	-1.791799	207.2377	
MW5	5	0.34	14.68	1.6094379	215.48861	215.514722
BS-3	14	0.17	14.69	2.6390573	215.66884	215.634908
BS-2	15.5	0.18	14.69	2.74084	215.65824	215.646789
MW1	60	0.06	14.69	4.0943446	215.78551	215.804781
1% vacuum	0.082	14.69				

Regression parameters	
215.33	intercept, Bo
0.12	slope, B1
0.95	r ²

1% radius	42 feet
-----------	---------

Notes:

bioventing well: BV-1

injection rate: 5 scfm

H₂O - water

psia - pounds per square inch, absolute

scfm - standard cubic feet per minute

TABLE 2-6

SHORT-TERM BIOVENTING TEST DATA FOR INJECTION WELL BV-2

Observation Point	r, distance (feet)	P, vacuum ("H ₂ O)	P, vacuum (psia)	ln r	P2	Regression
	0.16666	10.10	14.33	-1.791799	205.26737	
MW5	10.5	0.22	14.68	2.3513753	215.61583	215.615239
BS-3	17	0.16	14.69	2.8332133	215.67945	215.66258
BS-1	15.5	0.2	14.68	2.74084	215.63703	215.653505
MW1	60	0.06	14.69	4.0943446	215.78551	215.786488
1% vacuum	0.101	14.69				

Regression parameters	
215.38	intercept, B ₀
0.10	slope, B ₁
0.97	r ²

1% radius	38 feet
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Notes:

bioventing well: BV-2

injection rate: 5 scfm

H₂O - water

psia - pounds per square inch, absolute

scfm - standard cubic feet per minute

TABLE 2-7

EXTENDED BIOVENTING TEST DATA

Date	BV-1		BV-2		BV-3		MW-5		Cycle Parameters
	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	O ₂ (%volume)	CO ₂ (%volume)	
1/5/2004	20.6	0	20.6	0	20.6	0	nm	nm	
1/9/2004	0.2	7.5	4.8	3.3	2.4	4.9	0.2	6.4	OFF since 1/5, turned ON at 6 scfm
2/2/2004	0.3	13	4.3	5.1	nm	nm	nm	nm	OFF since 1/27, turned ON at 6 scfm
2/9/2004	0.2	7.6	3.6	5.2	7.5	3.8	1.9	5.7	OFF since 2/6, turned ON at 6 scfm
2/23/2004	0.3	4.9	3.8	2.8	nm	nm	7.8	3	OFF since 2/19, turned ON at 6 scfm
3/4/2003	1.2	5.4	11	1	11.1	1.4	3.9	4.8	OFF since 3/1, turned ON at 6 scfm
3/15/2004	0.3	8.2	7.5	2.8	11.2	1.9	0.7	8.2	OFF since 3/11, turned ON at 6 scfm
3/28/2004	0.1	3.9	3.1	2.9	3.7	2.6	0.2	5.3	OFF since 3/23, turned ON at 5 scfm

*Notes:*CO₂ - carbon dioxide

nm - not measured

O₂ - oxygen

scfm - standard cubic feet per minute

TABLE 3-1

OXYGEN USE REGRESSION ANALYSES FOR RESPIROMETRY TEST I

	O ₂ (%volume)									
date	BV-1	BV-2	BV-3	MW-5	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6
10/17/2003	19.9	19.7	18.9	19.9	16.9	19.7	20.3	20.3	9.2	15.1
10/20/2003	17.5	16.5	10.4	11.7	13.5	16.5	16	13.2	13.3	14.1
10/24/2003	9.6	12.5	10.7	10.6	11.3	18.7	20	14.5	11	14.2
10/29/2003	5.7	8.1	4.2	6	8	11.5	11.4	9.2	10.2	11.8
11/3/2003	0.2	0.8	0	0.2	1.2	19	3.7	5.3	0	10.6
Regression Parameters	BV-1	BV-2	BV-3	MW-5	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6
k (%/day)	-1.18	-1.08	-1.01	-1.03	-0.86	-0.13	-0.91	-0.78	-0.54	-0.27
r ²	0.98	0.99	0.92	0.94	0.97	0.07	0.80	0.89	0.53	0.94
in hydrocarbon-affected soil?	yes	yes	yes	yes	no	no	no	no	no	no

k _{total-avg}	-1.08	= average k value in hydrocarbon-affected soil
k _{diff-avg}	-0.58	= average k value in clean soil
k _{resp-avg}	-0.49	= k _{total-avg} - k _{diff-avg}

Notes:

O₂ - oxygen

TABLE 3-2

OXYGEN USE REGRESSION ANALYSES FOR RESPIROMETRY TEST II

Date	O ₂ (%volume)									
	BV-1	BV-2	BV-3	MW-5	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6
11/10/2003	20.5	20.1	19.1	20.7	19.7	12.4	17	16.9	15.4	12.5
11/11/2003	11.9	15.9	14.2	15.9	15.6	15.2	17.5	16.3	15	12.7
11/13/2003	1.4	6	3.6	1	7.7	13.2	20.3	10.5	10.5	14.3
Regression Parameters	BV-1	BV-2	BV-3	MW-5	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6
k (%/day)	-6.21	-4.74	-5.19	-6.69	-3.99	0.09	1.14	-2.24	-1.72	0.63
r ²	0.98	1.00	1.00	0.99	1.00	0.01	0.96	0.94	0.93	0.95
in hydrocarbon-affected soil?	yes	yes	yes	yes	no	no	no	no	no	no

$k_{\text{total-avg}}$	-5.71	= average k value in hydrocarbon-affected soil
$k_{\text{diff-avg}}$	-1.02	= average k value in clean soil
$k_{\text{resp-avg}}$	-4.69	= $k_{\text{total-avg}} - k_{\text{diff-avg}}$

Notes:

O₂ - oxygen

TABLE 3-3

OXYGEN UTILIZATION REGRESSION ANALYSES FOR RESPIROMETRY TEST III

Date	O ₂ (%volume)									
	BV-1	BV-2	BV-3	MW-5	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6
12/3/2003	20.6	20.8	19.4	20.6	20	15.8	19.7	20.7	17.4	18
12/5/2003	4.5	14.2	13.2	7.6	11.2	14.5	18.5	20.3	14.7	16.4
12/8/2003	0.2	2.5	0.2	0.4	7.7	12	14.7	15.7	12	16.8
Regression Parameters	BV-1	BV-2	BV-3	MW-5	SP-1	SP-2	SP-3	SP-4	SP-5	SP-6
k (%/day)	-3.87	-3.68	-3.88	-3.91	-2.36	-0.77	-1.02	-1.04	-1.07	-0.21
r ²	0.82	1.00	0.99	0.92	0.88	1.00	0.97	0.89	0.99	0.40
in hydrocarbon-affected soil?	yes	yes	yes	yes	no	no	no	no	no	no

$k_{\text{total-avg}}$	-3.83	= average k value in hydrocarbon-affected soil
$k_{\text{diff-avg}}$	-1.08	= average k value in clean soil
$k_{\text{resp-avg}}$	-2.76	= $k_{\text{total-avg}} - k_{\text{diff-avg}}$

Notes:

O₂ - oxygen

TABLE 3-4

SOIL SAMPLE RESULTS FOR NEW PROBE BV-4, BV-5, AND BV-6 INSTALLATION, UST SITE 43402

Soil Boring ID	Date Sampled	Sample ID	Depth (feet below grade)	TPH-d mg/kg	Nutrients				
					Ammonia-Nitrogen mg/kg	Nitrate-Nitrite-Nitrogen mg/kg	Orthophosphate-Phosphorous mg/kg	Hydrocarbon-Oxidizing Microbial Population MPN/g	Moisture % wt
B34-BV4	20-Apr-04	0063-060/061/062	21.5 to 23	28,000	10.2	10.4	< 2.0	4.3 x 10 ¹	14.1
B35-BV5	21-Apr-04	0063-068/069/070	18 to 22	ND	10.7	13.2	< 2.0	7.4 x 10 ⁰	13.7
B35-BV5 Dup	21-Apr-04	0063-071	22.5	ND	na	na	na	na	na
B36-BV6	21-Apr-04	0063-065/066/067	17-22	6,700	13.7	18.5	< 2.0	6.7 x 10 ¹	3.8
Reporting Limits				10	5.0	0.5	0.2	0.2 x 10 ¹	

Notes:

Dup - Field duplicate sample

EPA - U.S. Environmental Protection Agency

mg/kg- milligrams per kilogram

MPN-g - Most Probable Number/gram

na - not analyzed

ND - Not detected above laboratory detection limits

TPH-d - total extractable petroleum hydrocarbons quantified as diesel

UST - Underground Storage Tank

TABLE 3-5

NUTRIENT TEST FIELD DATA

Date/Time	Cycle #	Cycle Mode	Day of Cycle	Air Injection Rate (scfm)	Influent Gas			MW5/BV-3			P1			P2			P3		
					N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂	N ₂ O (ppmv)	%O ₂	%CO ₂
4/27/2004	baseline							0	3.0/0.7	5.1/6.2	0	1.5/2.9	11.6/4.2	0	9.2	7.5	0	2.7/7.8	7.5/3.6
4/27/2004	1	ON	1	5	612	20.7	0												
4/28/2004	1	ON	2	5	640	20.7	0	385/618	20.3/17.3	0.2/1.2	37	0.8	13.2	117	4.2	5.2	618	16.8	1.6
4/29/2004	1	ON	3	5	27	20.7	0	152/623	20.7/18.2	0.1/1.7	618	1.4	14.1	619	6.9	10.3	618	18.2	1.4
5/3/2004	1	ON	7	5	4	20.7	0	9.9/15.2	20.6/19.5	0/0.6	637	0.8	14.8	658	10	10	7.1	18.5	1.1
5/5/2004	1	ON	9	5	nm	nm	nm	62/615	20.6/19.4	0/0.7	619/650	1.3/1.4	14.0/9.2	625	10.3	8.9	592	18.4	1
5/6/2004	1	ON	10	5	nm	nm	nm	619/612	19.6/19.2	0/0.5	637	1.4	14.8	629	10.3	8.8	622	18	0.9
5/7/2004	1	OFF	1	-	650	14.1	0	626/628	13.9/18.2	1.1/0.7	607	1	15	nm	nm	nm	618	15.2	2.2
5/10/2004	1	OFF	4	-	626	1	6.7	637/618	1.2/6.4	6.7/4.9	608	1.7	14.4	608	10.1	8.8	622	7.9	5.5
5/12/2004	1	OFF	6	-	645	0.8	7.1	639/626	3.3/1.4	6.3/8.6	nm	nm	nm	624	9.8	9.8	nm	3.5	8
5/16/2004	2	ON	1	15	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
5/17/2004	2	ON	6	10	nm	20.7	0	nm	20.2/20.5	0/0	nm	0.8	9.1	nm	16.2	3.2	nm	20.2	0.2
5/20/2004	2	ON	9	12.5	nm	20.7	0	nm	19.9/19.9	0/0.1	nm	1.7	12	nm	15.1	3.1	nm	19.6	0

Notes

CO₂ - carbon dioxideN₂O - nitrous oxide

nm - not measured

O₂ - oxygenppmv - parts per million by volume

scfm - standard cubic feet per minute

TABLE 3-6

LABORATORY ANALYTICAL RESULTS FOR NUTRIENT TEST

Time/Date	Ethanol Concentration								Sampling Event Description
	Influent		P-1		P-2		P-3		
	(ppbv)	(mg/m ³)	(ppbv)	(mg/m ³)	(ppbv)	(mg/m ³)	(ppbv)	(mg/m ³)	
4/27/04	1459	2835.00	na	na	na	na	na	na	baseline
4/28/04	na	na	213.9J	415.5J	ND	ND	ND	ND	progress #1, Cycle #1
5/3/04	436.1J	847.1J	ND	ND	ND	ND	ND	ND	progress #2, Cycle #1
5/6/04	ND	ND	ND	ND	ND	ND	ND	ND	eND Cycle #1
5/17/04	204.4J	397.1J	ND	ND	ND	ND	ND	ND	progress #1, Cycle #2

Notes:

J - estimated value

mg/m³ - milligrams per cubic meter

na - not analyzed

ND - not detected

ppbv - parts per billion by volume

FIGURES

Figure 3-1
Respiratory Gas and Dissolved Oxygen Levels
for Biosparging Test and Respirometry Test I

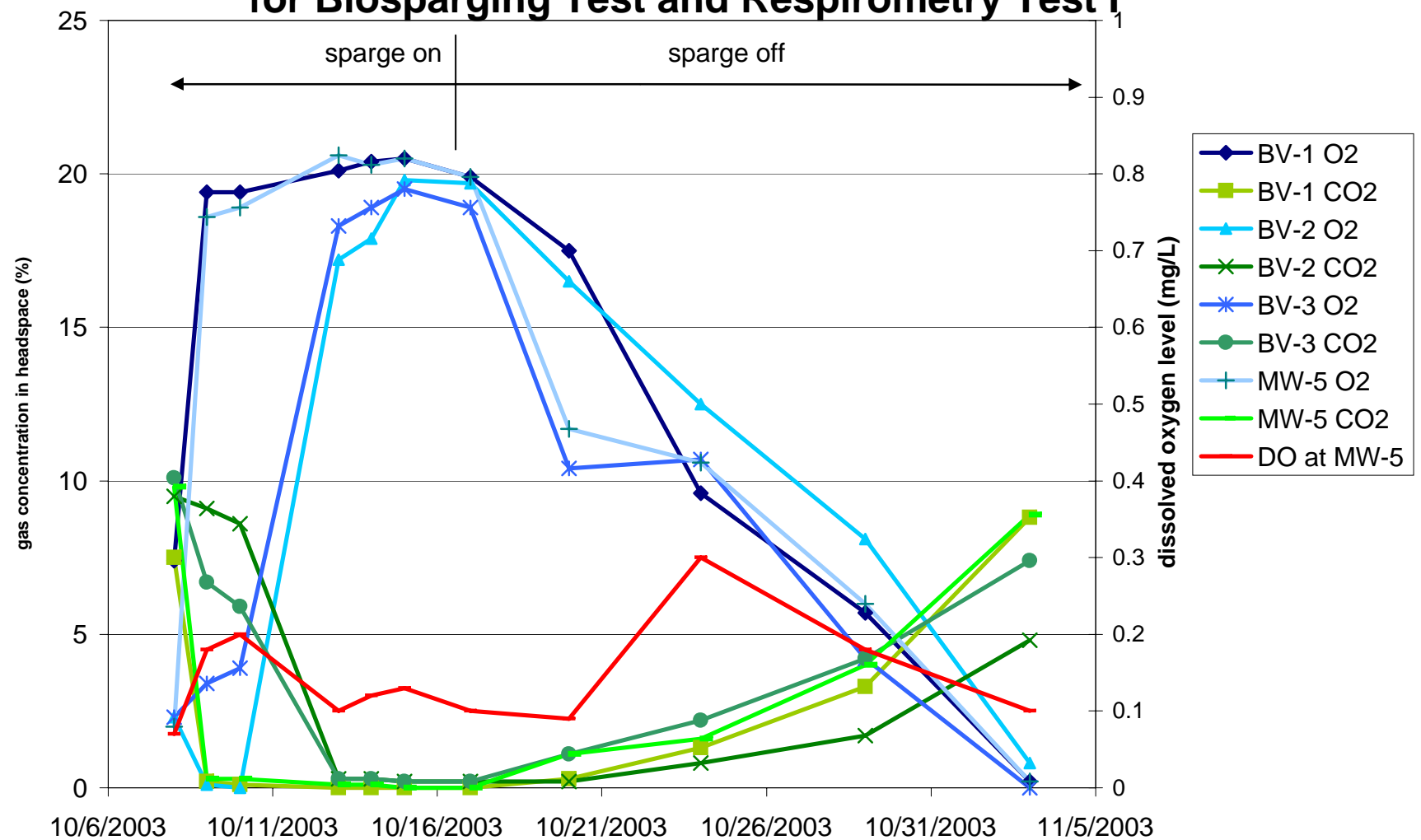


Figure 3-2
Respiratory Gas Levels for Respirometry Test II

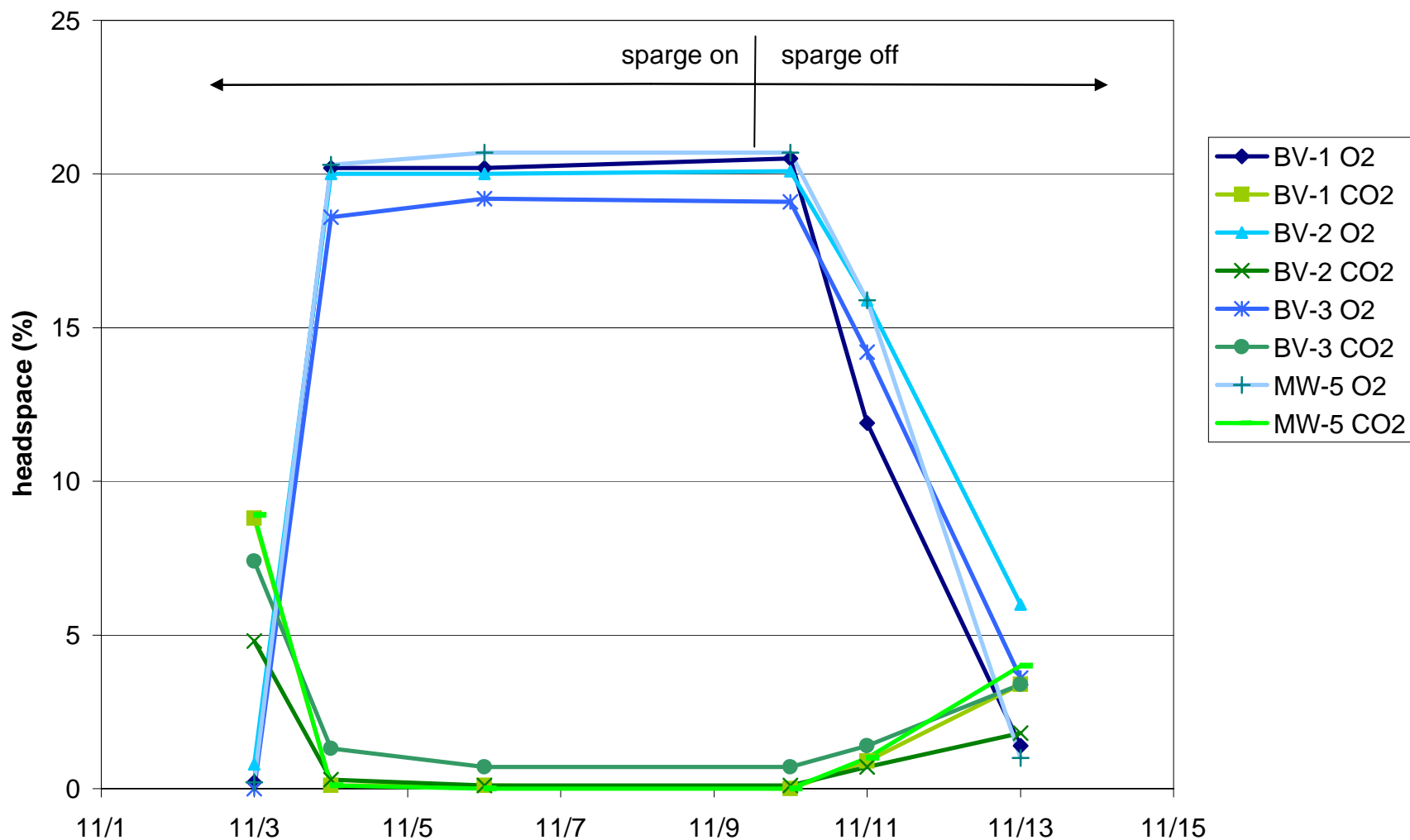


Figure 3-3
Respiratory Gas Levels for Respirometry Test III

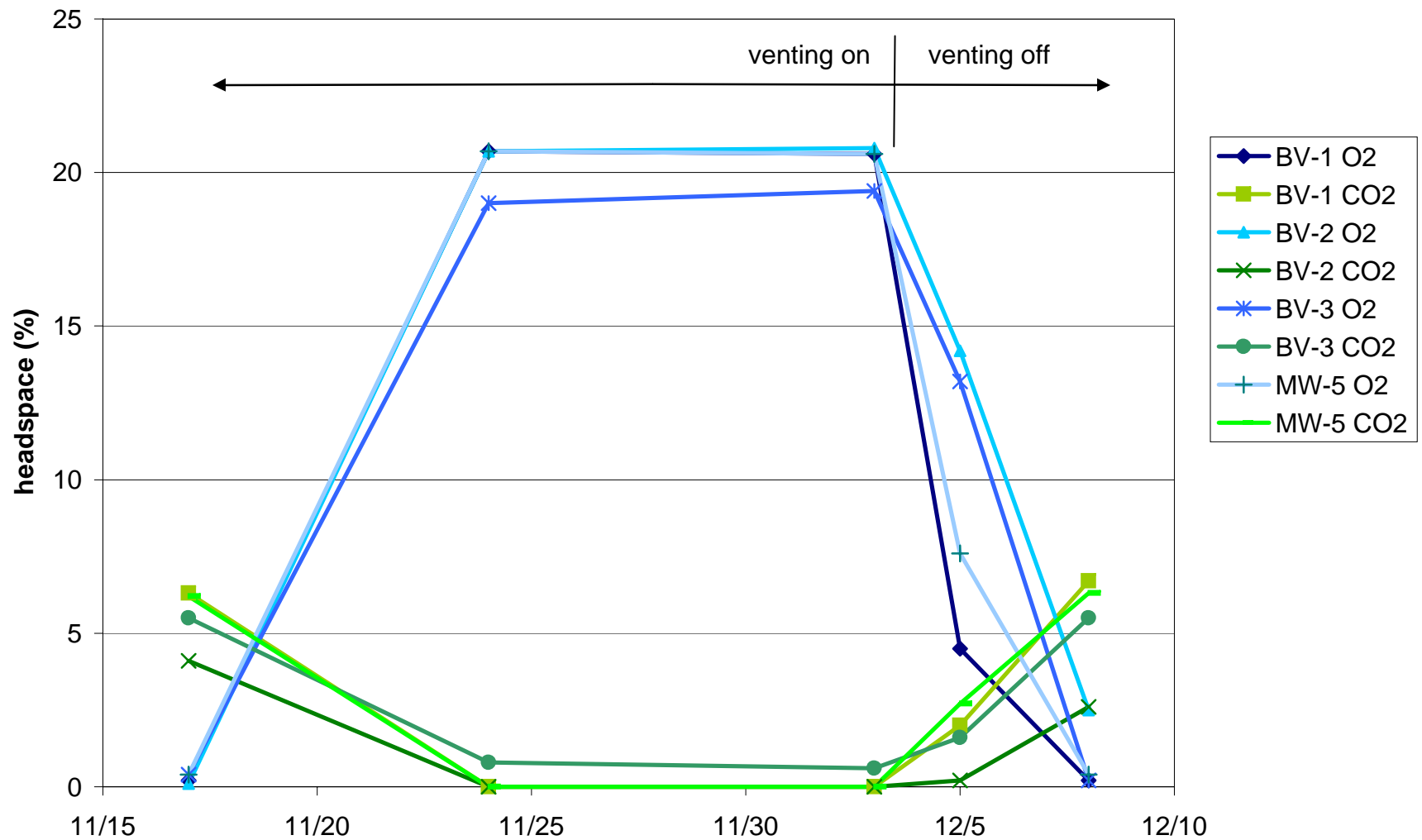


Figure 3-4

VOC Concentration-Oxygenation Correlation

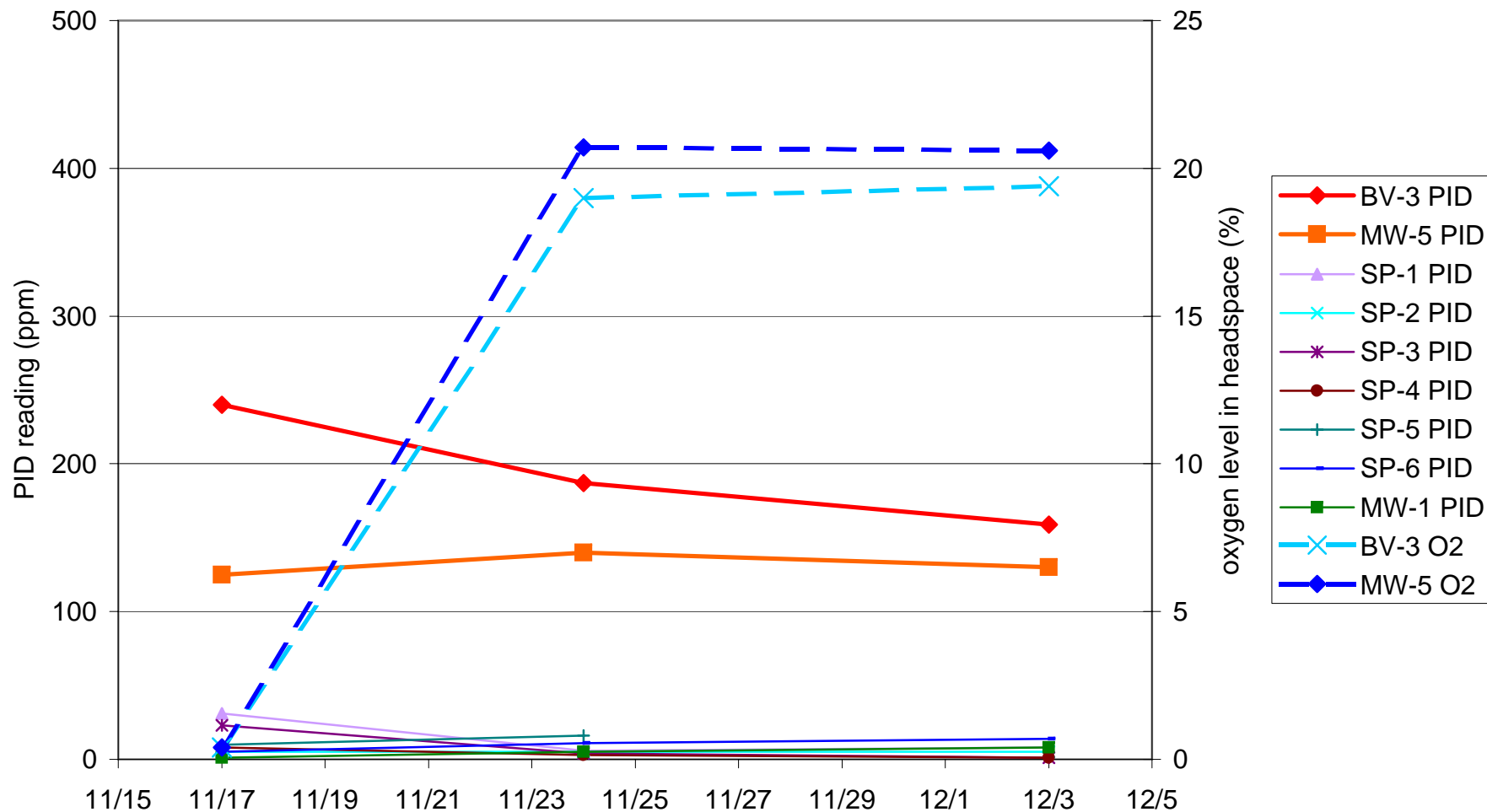


Figure 3-5
CO₂ Production Rates During Extended
Bioventing Test

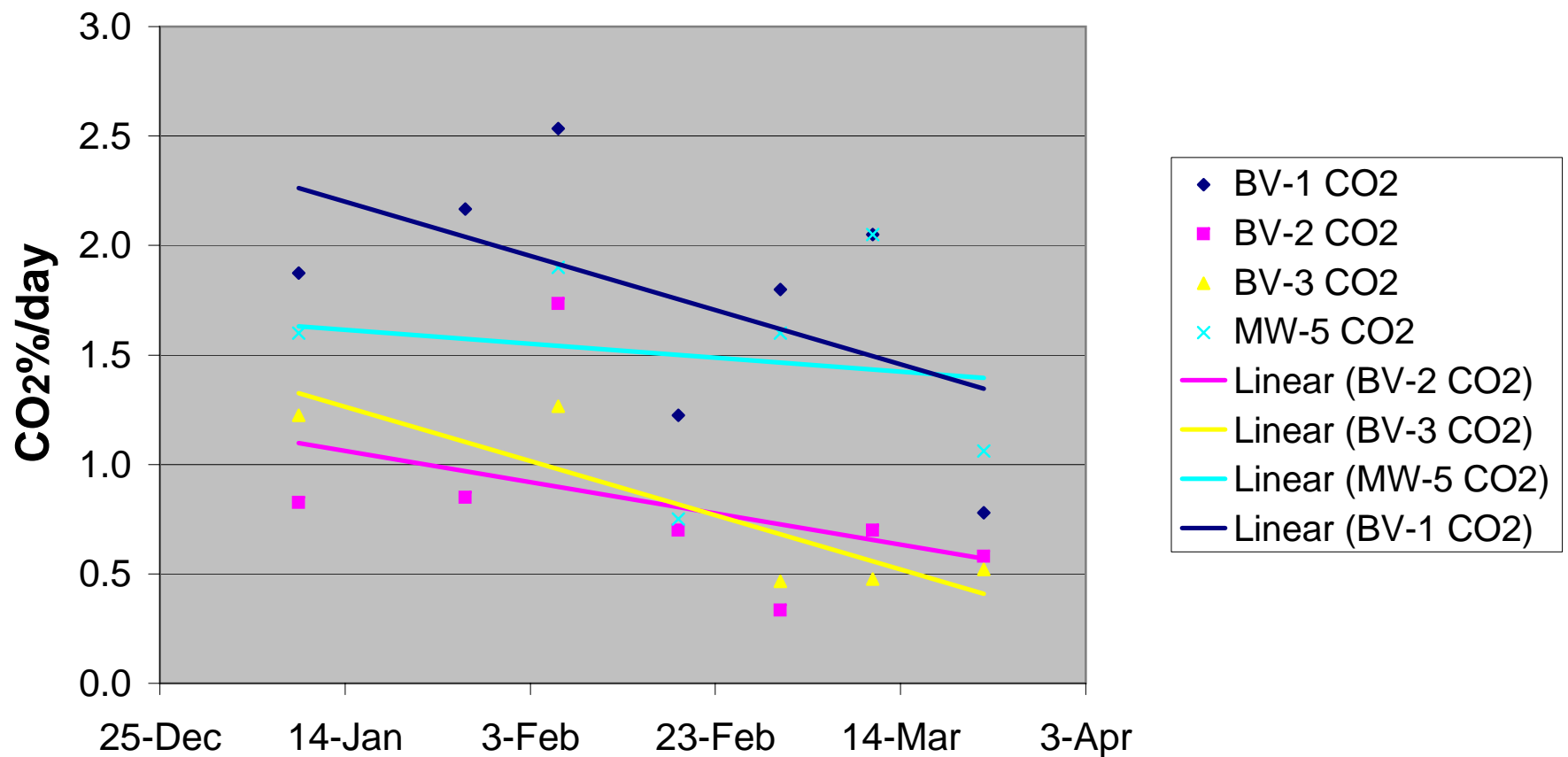
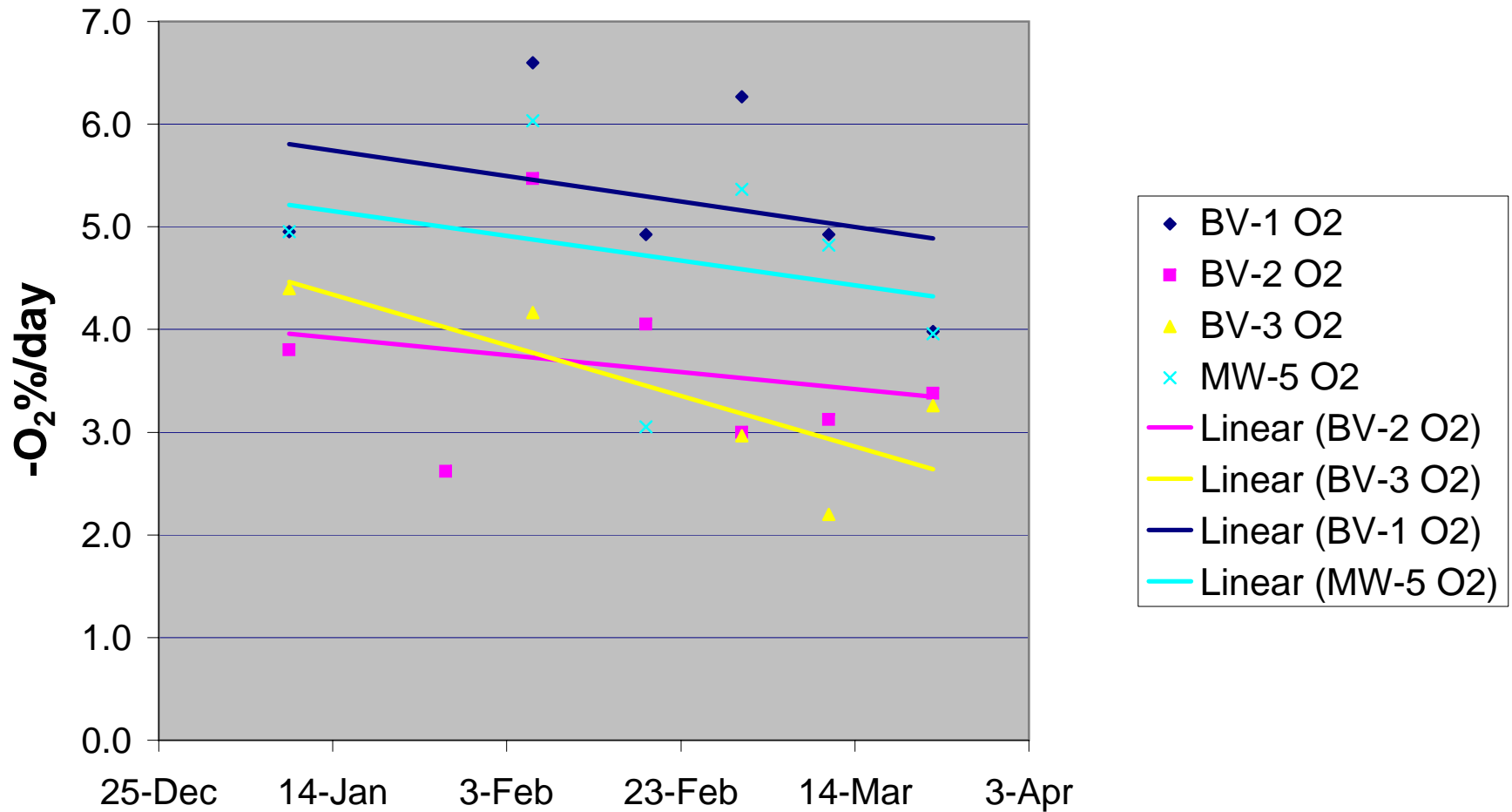


Figure 3-6
O₂ Utilization Rates
During Extended Bioventing Test



ATTACHMENT 1

BIOVENT WELL PERMIT AND BORING LOGS



PERMIT #W101324
A.P.N. #101-520-14
EST #H05939-236

**COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH
LAND AND WATER QUALITY DIVISION**

MONITORING WELL CONSTRUCTION PERMIT

SITE NAME: UST SITE 43-402

SITE ADDRESS: MARINE CORPS BASE, CAMP PENDLETON, CA 92055

PERMIT TO: **INSTALL 3 GROUND WATER MONITORING WELLS**

PERMIT APPROVAL DATE: MAY 29, 2003

PERMIT EXPIRES ON: SEPTEMBER 26, 2003

PERMIT CONDITIONS:

1. **Contact the Regional Water Quality Control Board for their comments and concerns regarding the proposed activities**
2. wells must have a **minimum 3-foot concrete surface seal**. The surface seal shall consist of concrete able to withstand the maximum anticipated load without cracking or deteriorating. The concrete should meet Class A specifications of a minimum 4000-pound compressive strength.
3. All water and soil resulting from the activities covered by this permit must be managed, stored and disposed of as specified in the SAM Manual in Section 5, E- 4. (http://www.sdcountry.ca.gov/deh/lwq/sam/manual_guidelines.html). In addition, drill cuttings must be properly handled and disposed in compliance with the Stormwater Best Management Practices of the local jurisdiction.
4. Within 60 days of completing work, submit a well construction report, including all well and/or boring logs and laboratory data to the Well Permit Desk. This report must include all items required by the SAM Manual, Section 5, Pages 6 & 7.
5. This office must be given 48-hour notice of any drilling activity on this site and advanced notification of drilling cancellation. Please contact the Well Permit Desk at 338-2339.

APPROVED BY: _____

Carol Spangenberg
CAROL SPANGENBERG

DATE: 05/29/2003

NOTIFIED: V.M. ms9 5/29/03 *msc*



PERMIT APPLICATION
GROUNDWATER
AND

VADOSE MONITORING WELLS
AND EXPLORATORY OR TEST BORINGS

OFFICE USE ONLY

PERMIT#: W 101324
SAM CASE #YN H 05937
DATE RECEIVED: 5-16-03
FEE PAID: \$430-4009325

RECEIVED

MAY 16 AM 11 06

D. F. H.
MAILROOM

A. RESPONSIBLE PARTY Marine Corps Base Camp Pendleton Phone (760)725-9744
Mailing Address Building 22165, Area 22 City Camp Pendleton State California Zip 92055-5008
Contact Person Tracy Sahagun, AC/S Environmental Security Phone (760)725-9774 ext. _____

B. SITE ASSESSMENT PROJECT IF APPLICABLE #H 05939-236

C. CONSULTING FIRM Tetra Tech FW
Mailing Address 1940 E. Deere St. Suite 200 City Santa Ana State California Zip 92705
Registered Professional Mark Cutler Registration # 4487 (RG, RCE, CEG)
Contact Person Mark Cutler Phone (949) -756-7526 ext. _____

D. DRILLING COMPANY West Harnat Drilling C57# 819548 Phone (619) 686-5800
Mailing Address 3620 Kuntz Street City San Diego State CA Zip 92110

E. CONSTRUCTION INFORMATION

TYPE OF WELLS/ BORINGS TO BE CONSTRUCTED	MATERIALS TO BE USED	PROPOSED CONSTRUCTION
<input checked="" type="checkbox"/> <u>bioremediation</u> # <input checked="" type="checkbox"/> Groundwater <u>3</u> <input type="checkbox"/> Boring _____ <input type="checkbox"/> Other _____	CASING Type <u>PVC</u> Gauge <u>Sch. 40 or 80</u> Diameter <u>2-inch</u> Well Screen Size <u>0.010-inch</u> Filter Pack _____ (Specify) <u>Lonestar #2/16 or equivalent</u> SEAL <input type="checkbox"/> Neat Cement <input checked="" type="checkbox"/> Cement & Bentonite <input type="checkbox"/> Sand-Cement <input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Other _____ Drilling Method <input checked="" type="checkbox"/> Auger <input type="checkbox"/> Air Rotor <input type="checkbox"/> Mud Rotary <input type="checkbox"/> Other <input type="checkbox"/> Percussion	PROPOSED CONSTRUCTION SITE 43402 Estimated depth to ground water 28 ft. CEMENT SEAL <u>SURFACE</u> to <u>3 feet</u> BENTONITE SEAL <u>3 feet</u> to <u>28 feet</u> FILTER PACK <u>28 feet</u> to <u>35 feet</u> PERFORATION <u>30 feet</u> to <u>35 feet</u> PROPOSED CONSTRUCTION SITE 210620 Depth to ground water NA (vadoze only) CEMENT SEAL <u>SURFACE</u> to <u>3 feet</u> BENTONITE SEAL <u>3 feet</u> to <u>38 feet</u> FILTER PACK <u>38 feet</u> to <u>50 feet</u> PERFORATION <u>40 feet</u> to <u>50 feet</u> PROPOSED DRILLING DATE _____

I agree to comply with the requirements of the current Site Assessment and Mitigation Division Manual, and with all ordinances and laws of the County of San Diego and the State of California pertaining to well/boring construction and destruction.

Mark Cutler
DRILLER'S SIGNATURE

5/15/03
DATE

Within 30 days of completion, I will furnish the Monitoring Well Permit Clerk with a complete and accurate well/boring log. I will certify the design and construction/or destruction of the well/borings in accordance with the permit application.

Mark Cutler
RG/RCE/CEG SIGNATURE

4/1/03
DATE

F. SITE INFORMATION

520-14

1. ASSESSOR'S PARCEL NUMBER 101-000-000

Site Name Marine Corps Base Camp Pendleton, California, UST Site

Site Address Building 43402 43 Area City Camp Pendleton Zip 92055

PROPERTY OWNER United States Marine Corps, AC/S Environmental Security Phone (760)725-9774

Mailing Address Building 22165, Area 22 City Camp Pendleton State CA Zip 92055-5008

NUMBER OF WELLS 3 Well Boring TYPE OF WELLS Groundwater monitoring

2. ASSESSOR'S PARCEL NUMBER 101-000-000

Site Name Marine Corps Base Camp Pendleton, California, UST Site

Site Address Building 21020 21 Area City Camp Pendleton Zip 92055

PROPERTY OWNER United States Marine Corps, AC/S Environmental Security Phone (760)725-9774

Mailing Address Building 22165, Area 22 City Camp Pendleton State CA Zip 92055-5008

NUMBER OF WELLS 2 Well Boring TYPE OF WELLS Vapor extraction wells

G. FEES (in effect beginning Jan. 10, 2003, through June 30, 2003):

ACTIVITY	FEE SCHEDULE	AMOUNT
Permit for Well Installations Only (Groundwater Monitoring Wells Vadose, Vapor Extraction Wells)	\$160.00 for the first well \$135.00 for each additional well	<u>1</u> x \$160.00 <u>\$ 160.00</u> <u>4</u> x \$135.00 <u>\$ 540.00</u>
Permit for Borings Only (Hydropunch, Geoproses, Temporary Well Points, etc.)	\$160.00 for the first boring \$40.00 for each additional boring	<u> </u> x \$160.00 \$ <u> </u> <u> </u> x \$ 40.00 \$ <u> </u>
Permit for Well Destructations Only	\$160.00 for the first destruction \$105.00 for each additional destruction	<u> </u> x \$160.00 \$ <u> </u> <u> </u> x \$105.00 \$ <u> </u>
Permit for any Combination of Well Installations, Borings & Destructations (except UST backfill permit)	The first activity (of any type) will be \$160.00. Additional activities will be as follows: \$135.00 for each well \$ 40.00 for each boring \$105.00 for each well destruction	<u> </u> x \$160.00 \$ <u> </u> <u> </u> x \$135.00 \$ <u> </u> <u> </u> x \$ 40.00 \$ <u> </u> <u> </u> x \$105.00 \$ <u> </u>
Permit for Underground Storage Tank Monitoring System in Backfill (i.e. enhanced leak detection)	\$300.00 (Flat Fee)	\$ <u> </u>
	TOTAL COST OF PERMIT	<u>\$700.00</u>

H. APPLICATION SUBMITTAL, PLAN APPROVAL, PERMIT ISSUANCE, AND REQUIRED INSPECTIONS

Submit one (1) original and two (2) copies of this application package, including plan drawings with the required fee to the Department of Environmental Health, Site Assessment and Mitigation Division (SAM). 1255 Imperial Avenue, San Diego, CA 92101. Or mail to P. O. Box 129261, San Diego, CA 92112-9261. **Checks should be made payable to the County of San Diego.**

A permit will be issued by SAM upon review and approval of the application and plans. The required fees must be submitted with the application package. Information in addition to that presented in the application package may be needed in order to obtain final approval. No work is to begin on the proposed project until a permit has been issued. The required inspections cannot be scheduled until a permit is issued.

Once the permit has been issued, it is the responsibility of the permittee to notify SAM at least two (2) working days in advance to schedule each required inspection.

USE ONE APPLICATION PACKAGE FOR A SINGLE SITE PROJECT. A SINGLE PERMIT WILL BE ISSUED FOR A SINGLE SITE PROJECT, EVEN IF WELLS/BORINGS ARE COMPLETED ON MORE THAN ONE PROPERTY. FOR MULTIPLE SITE PROJECT'S, USE SEPARATE APPLICATIONS.

PERMIT APPLICATION FOR
GROUND WATER AND VADOSE MONITORING WELLS
EXPLORATORY OR TEST BORINGS

- For well destruction, complete only #1 below.
 - Well design, logging and construction must be supervised by a Geologist, Engineering Geologist or Civil Engineer who is registered or certified by the State of California.
 - Well driller must have an active C-57 License and current \$2,500 bond with the County.
 - Provide a plot plan giving location of property lines, existing improvements such as structures, underground tanks, underground utilities, underground piping, and the proposed monitoring and/or observation wells.
 - If applicable, provide a signed copy of the Property Owner Responsibility form for each property listed in Section "F".
 - Provide encroachment/excavation permit and/or traffic control permit for work to be done in street or public right of way.
1. If wells are to be destroyed, provide a description of method of destruction. NA
 2. What is the proposed purpose of the well/boring? At Site 43402 wells will be used to support a biovent/biosparge pilot test; at Site 210620 wells will be used to support a soil vapor extraction pilot test.
 3. What procedures will be used to prevent the well/boring from providing an avenue to contamination during construction? All drilling and sampling equipment will be decontaminated prior to drilling, appropriate well construction and backfill procedures will be followed in accordance with the SAM 2003 manual and the California Well Standards Bulletin 74-90 and Bulletin 74-81.
 4. What field procedures will be utilized to determine if contamination exists? A Photo-Ionization Detector (PID) or other similar device will be used to screen soil cuttings and samples.
 5. What procedures will be used to determine whether samples will be sent for laboratory testing or archiving? Discrete intervals will be sampled/tested based on project requirements and samples with highest PID Readings.
 6. What constituents will be monitored and tested (Include EPA Laboratory Test Methods to be used)? The following constituents will be analyzed or at Site 43402:
 - TPH quantified as diesel by USEPA Method 8015B
 - BTEX and MTBE by USEPA Method 8021
 - PAHs by USEPA Method 8310

The following constituents will be analyzed or at Site 210620:

- TPH-quantified as gasoline by USEPA Method 5035/8015B
- VOCs (including BTEX and MTBE) by USEPA Method 5035/8260B
- Total lead by USEPA Method 6010B

7. How will samples be transported and preserved. Samples will be stored in a cooler with ice, and transported directly to the laboratory. In addition, samples will be accompanied by appropriate Chain of Custody documentation.
8. What sampling methods will be used? Continuous core sampling will be conducted.
9. Are you proposing a variation from the methods and/or procedures presented in the requirements for the construction of Vadose and Ground Water Monitoring Wells (Current SAM Manual Requirements). If yes, specify these variations. NO.
10. What procedures will be used to ensure no contamination will be introduced by the drilling equipment?
All drilling equipment will be decontaminated prior to use and between boring locations.
11. What methods will be used to clean sampling equipment? All sampling equipment will be washed in a detergent solution, rinsed with potable water and rinsed again with deionized water
What cleaning method will be used to clean casing and screen prior to installation? Materials will arrive on-site pre-cleaned.

DRAWING NO:

03083911.DWG

DCN: FWSO-RAC-03-0839

CTO: #0024

APPROVED BY: MC

CHECKED BY: DO

REV: REVISION 0

DRAWN BY: MD

DATE: 02/25/03

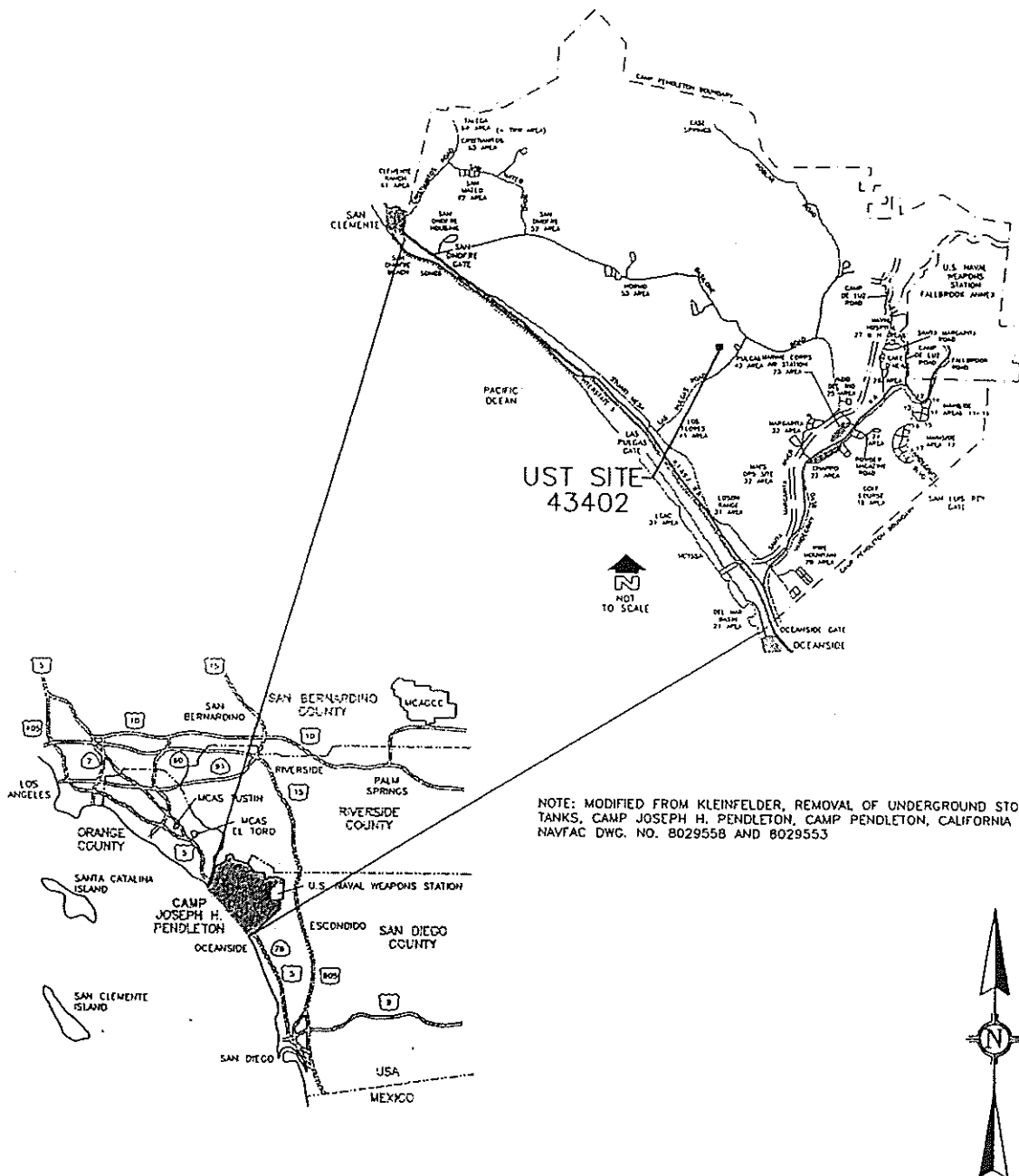
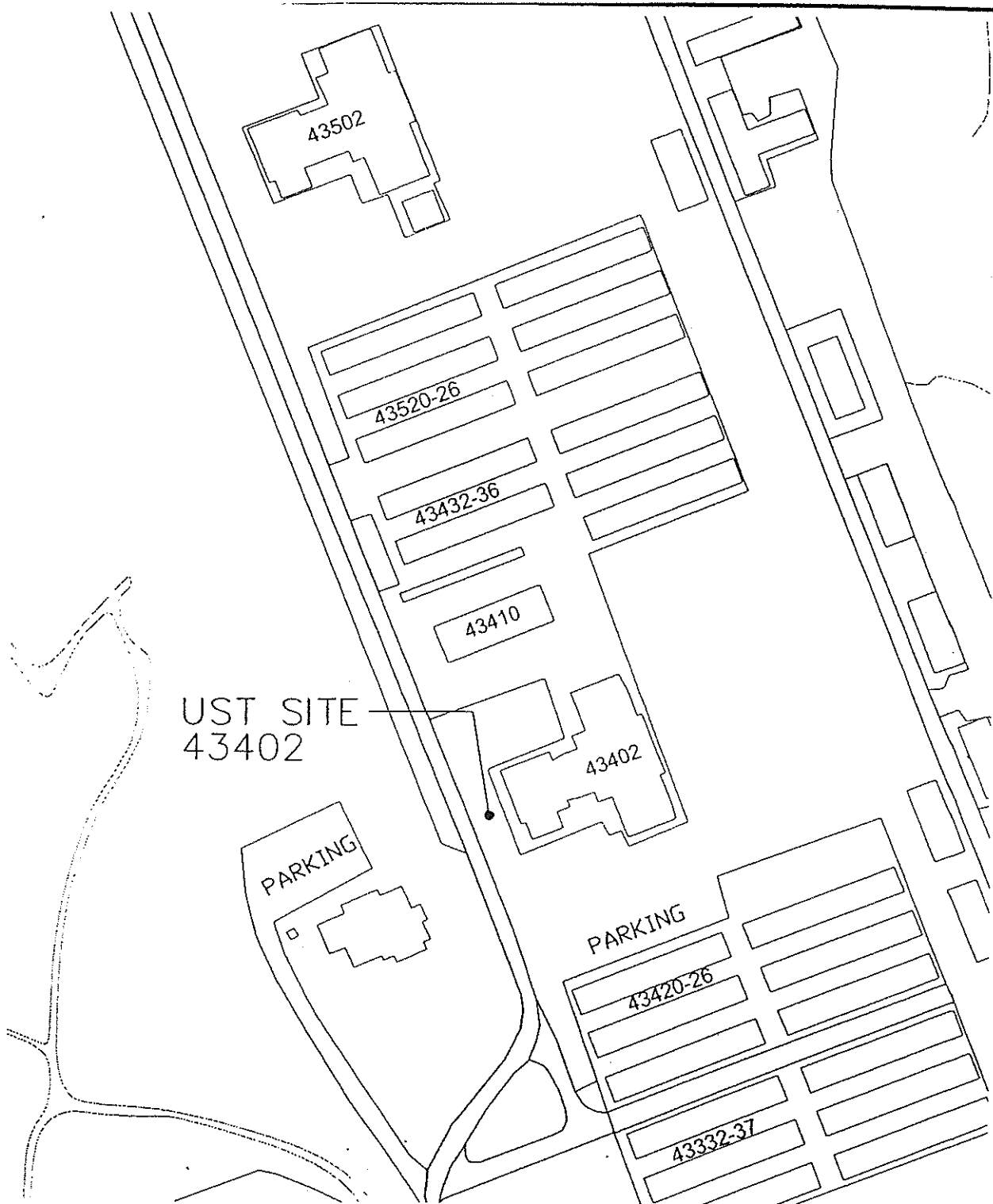


Figure 1-1
SITE VICINITY MAP

UST SITE 43402, MCB CAMP PENDLETON

FOSTER  WHEELER
ENVIRONMENTAL CORPORATION

DRAWN BY: MO	CHECKED BY: DO	APPROVED BY: MC	DCN: FWSO-RAC-03-0839	DRAWING NO: 03083912.DWG
DATE: 02/25/03	REV: REVISION 0		CTO: #0024	



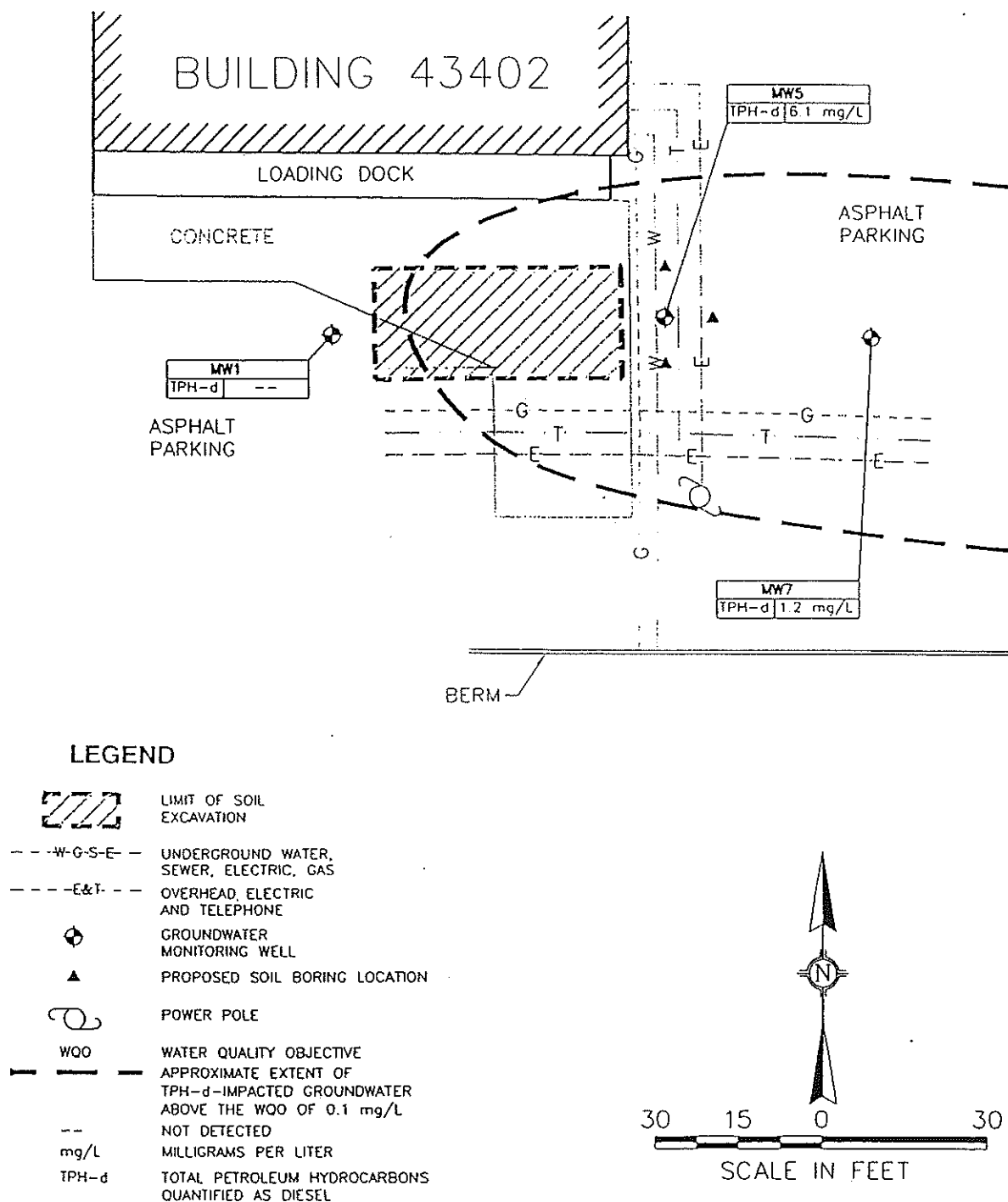
NOTE: MODIFIED FROM KLEINFELDER, REMOVAL OF UNDERGROUND STORAGE TANKS, CAMP JOSEPH H. PENDLETON, CAMP PENDLETON, CALIFORNIA NAVFAC DWG. NO. 8029647.

Figure 1-2 SITE LOCATION MAP

UST SITE 43402, MCB CAMP PENDLETON

FOSTER  WHEELER
ENVIRONMENTAL CORPORATION

DRAWN BY: MD	CHECKED BY: DO	APPROVED BY: MC	DCN: FWSO-RAC-03-0839	DRAWING NO: 03083931.DWG
DATE: 02/25/03	REV: REVISION 0		CTO: #0024	



FOSTER WHEELER **ENVIRONMENTAL CORPORATION**

LOG OF BORING **43402-B31 (BS/BV-1)** (Sheet 1 of 2)

Client: SWDIV	Drilling Company: West Hazmat
Project: Continued Remediation of Multiple UST Sites	Drilling Method: Hollow-Stem Auger
Project Number: 1990.063D	Sampling Method: Continuous Core
Location: MCB Camp Pendleton	Borehole Diameter: 10 in. 0-30Ft.
Geologist: D. Dirkin	Northing: 2,071,772.00 Feet (NAD 83; NAVD 88)
Date Started: June 5, 2003	Easting: 6,207,078.00 Feet (NAD 83; NAVD 88)
Date Completed: June 5, 2003	Ground Surface Elevation: 252.40 Feet AMSL
Total Depth: 30.0 Feet bgs	Top of Casing Elevation: 251.90 Feet AMSL

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
0		Flush Mounted Traffic Box						0 to 17 ft. SILT: very dark gray, moist, moderately stiff, low plasticity, 85% non-plastic fines, 10% plastic fines, 5% fine sand, no hydrocarbon staining or odor observed	250
5		Concrete Backfill (1.2 cu ft)			0			Hand augered to 5-feet bgs for utility clearance	
		Hydrated Bentonite Chips (2 cu ft)							
		VP-1S (0.5" ID PVC)							
		VP-1D (0.5" ID PVC)							
		BV-1 (2" ID PVC)							
		BS-1 (2" ID PVC)							
10		2/16 Lonestar Sand (1 cu ft)			0	ML			245
		0.5" ID PVC Screen with 0.01" slots							
		Hydrated Bentonite Chips (1.5 cu ft)							
15		2/16 Lonestar Sand (1 cu ft)			0			SANDY SILT: dark yellowish brown, moist, moderately stiff, low plasticity, 45% non-plastic fines, 45% fine to medium subangular sand (predominantly fine grain), 10% plastic fines, micaceous, no hydrocarbon staining or odor observed	240
		0.5" ID PVC Screen with 0.01" slots							
		Hydrated Bentonite Chips (1.5 cu ft)							
						SP		17 to 23 ft. POORLY GRADED SAND: dark greenish gray, moist, moderately dense, 95% fine to coarse sand (predominantly fine to medium grain), 5% non-plastic fines, strong hydrocarbon odor and visible staining observed	235

Notes: Boring Log Reviewed By: M. Cutler 7/11/03

bgs = below ground surface
 AMSL = above mean sea level
 NA = not applicable
 NAD = North American Datum

SVP = Soil Vapor Probe
 VEW = Vapor Extraction Well
 ID = Internal Diameter
 PID = Photionization Detector
 PVC = Poly Vinly Chloride (Schedule 40)

FOSTER WHEELER **ENVIRONMENTAL CORPORATION**

LOG OF BORING **43402-B31 (BS/BV-1)** (Sheet 2 of 2)

Client: SWDIV	Drilling Company: West Hazmat
Project: Continued Remediation of Multiple UST Sites	Drilling Method: Hollow-Stem Auger
Project Number: 1990.063D	Sampling Method: Continuous Core
Location: MCB Camp Pendleton	Borehole Diameter: 10 in. 0-30Ft.
Geologist: D. Dirkin	Northing: 2,071,772.00 Feet (NAD 83; NAVD 88)
Date Started: June 5, 2003	Easting: 6,207,078.00 Feet (NAD 83; NAVD 88)
Date Completed: June 5, 2003	Ground Surface Elevation: 252.40 Feet AMSL
Total Depth: 30.0 Feet bgs	Top of Casing Elevation: 251.90 Feet AMSL

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
30.2		2/16 Lonestar Sand (2.2 cu ft)				SP		POORLY GRADED SAND: dark greenish gray, moist, moderately dense, 95% fine to coarse sand (predominantly fine to medium grain), 5% non-plastic fines, strong hydrocarbon odor and visible staining observed	230
		2" ID PVC Screen with 0.01-inch Slots							
25		Hydrated Bentonite Chips (1.5 cu ft)			20.6	SP		23 to 26 ft. POORLY GRADED SAND WITH GRAVEL: olive gray, moist, moderately dense, 80% fine to coarse sand, 15% fine to coarse subangular gravel, 5% non-plastic fines, strong hydrocarbon odor and visible staining observed	
		2/16 Lonestar Sand (2 cu ft)				ML		26 to 30 ft. SANDY SILT: dark greenish gray, wet, soft, moderate plasticity, 65% non-plastic fines, 25% fine to medium sand, 10% plastic fines, strong hydrocarbon odor and visible staining observed	225
30		2" ID PVC Screen with 0.01-inch Slots			26.6			Soil boring terminated by field geologist at 30 feet bgs Groundwater encountered at approximately 26 feet bgs Biosparge/Biovent well installed in accordance with design specifications	220
35									215

Notes: Boring Log Reviewed By: M. Cutler 7/11/03

bgs = below ground surface
 AMSL = above mean sea level
 NA = not applicable
 NAD = North American Datum

SVP = Soil Vapor Probe
 VEW = Vapor Extraction Well
 ID = Internal Diameter
 PID = Photoionization Detector
 PVC = Poly Vinyl Chloride (Schedule 40)

210620 SVE MULTI-COMPLETION WISS 063NEW-1.GPJ FSTRW_SAGDT 11/12/03

FOSTER WHEELER **ENVIRONMENTAL CORPORATION**

LOG OF BORING **43402-B32 (BS/BV-2)** (Sheet 1 of 2)

Client: SWDIV	Drilling Company: West Hazmat
Project: Continued Remediation of Multiple UST Sites	Drilling Method: Hollow-Stem Auger
Project Number: 1990.063D	Sampling Method: Continuous Core
Location: MCB Camp Pendleton	Borehole Diameter: 10 in. 0-30Ft.
Geologist: D. Dirkin	Northing: 2,071,773.00 Feet (NAD 83; NAVD 88)
Date Started: June 5, 2003	Easting: 6,207,088.00 Feet (NAD 83; NAVD 88)
Date Completed: June 5, 2003	Ground Surface Elevation: 252.40 Feet AMSL
Total Depth: 30.0 Feet bgs	Top of Casing Elevation: 251.90 Feet AMSL

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
0		Flush Mounted Traffic Box						0 to 17 ft. SANDY SILT: dark brown, moist, moderately stiff, moderate plasticity, 80% non-plastic fines, 15% plastic fines, 5% fine grain sand, no hydrocarbon staining or odor observed	250
5		Concrete Backfill (1.2 cu ft)			0			Hand augered to 5-feet bgs for utility clearance	
		Hydrated Bentonite Chips (2 cu ft)							
		VP-2S (0.5" ID PVC)							
		VP-2D (0.5" ID PVC)							
		BV-2 (2" ID PVC)							
		BS-2 (2" ID PVC)				ML		SANDY SILT: very dark gray, moist, moderate plasticity, 70% non-plastic fines, 30% plastic fines, no hydrocarbon staining or odor observed	245
10		2/16 Lonestar Sand (1 cu ft)			0				
		0.5" ID PVC Screen with 0.01" slots							
		Hydrated Bentonite Chips (1.2 cu ft)							
		2/16 Lonestar Sand (1 cu ft)			0				
15		0.5" ID PVC Screen with 0.01" slots						SANDY SILT: brown, moist, moderately stiff, low plasticity, 60% non-plastic fines, 35% fine to medium sand, 5% plastic fines, no hydrocarbon staining or odor observed	240
		Hydrated Bentonite Chips (1.5 bags)							
						SP		17 to 24 ft. POORLY GRADED SAND: dark greenish gray, moist, loose, 95% fine to coarse subangular to subrounded sand, 5% non-plastic fines, strong hydrocarbon odor and visible staining observed	235

Notes: Boring Log Reviewed By: M. Cutler 7/11/03

bgs = below ground surface
 AMSL = above mean sea level
 NA = not applicable
 NAD = North American Datum

SVP = Soil Vapor Probe
 VEW = Vapor Extraction Well
 ID = Internal Diameter
 PID = Photoionization Detector
 PVC = Poly Vinyl Chloride (Schedule 40)

210620 SVE MULTI-COMPLETION WISS 063NEW-1.GPJ FSTRW_SA.GDT 11/12/03

FOSTER WHEELER **ENVIRONMENTAL CORPORATION**

LOG OF BORING **43402-B32 (BS/BV-2)** (Sheet 2 of 2)

Client: SWDIV	Drilling Company: West Hazmat
Project: Continued Remediation of Multiple UST Sites	Drilling Method: Hollow-Stem Auger
Project Number: 1990.063D	Sampling Method: Continuous Core
Location: MCB Camp Pendleton	Borehole Diameter: 10 in. 0-30Ft.
Geologist: D. Dirkin	Northing: 2,071,773.00 Feet (NAD 83; NAVD 88)
Date Started: June 5, 2003	Easting: 6,207,088.00 Feet (NAD 83; NAVD 88)
Date Completed: June 5, 2003	Ground Surface Elevation: 252.40 Feet AMSL
Total Depth: 30.0 Feet bgs	Top of Casing Elevation: 251.90 Feet AMSL

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
23.0		2/16 Lonestar Sand (2.2 bags)			19.4	SP		POORLY GRADED SAND: dark greenish gray, moist, loose, 95% fine to coarse subangular to subrounded sand, 5% non-plastic fines, strong hydrocarbon odor and visible staining observed	230
25.0		2" ID PVC Screen with 0.01-inch Slots			19.6	SP-SM		24 to 26 ft. POORLY GRADED SAND WITH SILT: dark greenish gray, moist, moderately dense, 80% fine to coarse subangular to subrounded sand, 20% non-plastic fines, strong hydrocarbon odor and discoloration observed	225
26.0		Hydrated Bentonite Chips (1.5 cu ft)						26 to 30 ft. SANDY SILT: dark greenish gray to brown, wet, soft, moderate plasticity, 70% non-plastic fines, 20% fine to medium sand, 10% plastic fines, strong hydrocarbon odor and visible staining observed	
27.0		2/16 Lonestar Sand (2 cu ft)				ML		Slight hydrocarbon odor and discoloration observed	
28.0		2" ID PVC Screen with 0.01-inch Slots						No hydrocarbon staining or odor observed	
30.0					0			Soil boring terminated by field geologist at 30 feet bgs	
								Groundwater encountered at approximately 26 feet bgs	
								Biosparge/Biovent well installed in accordance with design specifications	220
35.0									215

Notes: Boring Log Reviewed By: M. Cutler 7/11/03

bgs = below ground surface
 AMSL = above mean sea level
 NA = not applicable
 NAD = North American Datum

SVP = Soil Vapor Probe
 VEW = Vapor Extraction Well
 ID = Internal Diameter
 PID = Photoionization Detector
 PVC = Poly Vinyl Chloride (Schedule 40)

FOSTER WHEELER **ENVIRONMENTAL CORPORATION**

LOG OF BORING **43402-B33 (BS/BV-3)** (Sheet 1 of 2)

Client: SWDIV	Drilling Company: West Hazmat
Project: Continued Remediation of Multiple UST Sites	Drilling Method: Hollow-Stem Auger
Project Number: 1990.063D	Sampling Method: Continuous Core
Location: MCB Camp Pendleton	Borehole Diameter: 10 in. 0-30FL
Geologist: D. Dirkin	Northing: 2,071,765.00 Feet (NAD 83; NAVD 88)
Date Started: June 6, 2003	Easting: 6,207,078.00 Feet (NAD 83; NAVD 88)
Date Completed: June 6, 503	Ground Surface Elevation: 252.40 Feet AMSL
Total Depth: 30.0 Feet bgs	Top of Casing Elevation: 251.90 Feet AMSL

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
0		Flush Mounted Traffic Box						0 to 0.5 ft. ASPHALT	
5		Concrete Backfill (1.2 cu ft) Hydrated Bentonite Chips (3.5 bags) VP-3S (0.5" ID PVC) VP-3D (0.5" ID PVC)			0			0.5 to 18 ft. SILT: very dark gray, moist, moderately stiff, low plasticity, 85% non-plastic fines, 10% plastic fines, 5% fine sand, no hydrocarbon staining or odor observed	250
10		Hand augered to 5-feet bgs for utility clearance			0	ML			
15		2/16 Lonestar Sand (1 cu ft) 0.5" ID PVC Screen with 0.01" slots			0			SANDY SILT: dark yellowish brown, moist, moderately stiff, non-plastic, 45% non-plastic fines, 50% fine to medium subangular to subrounded sand, 5% plastic fines, no hydrocarbon staining or odor observed	245
20		Hydrated Bentonite Chips (1.2 cu ft) 2/16 Lonestar Sand (1 cu ft) 0.5" ID PVC Screen with 0.01" slots			0				240
25		Hydrated Bentonite Chips (1.5 cu ft)			0				235
30		2/16 Lonestar Sand (2.2 cu ft)				SP		18 to 26.5 ft. POORLY GRADED SAND: dark greenish gray, moist, moderately dense, 95% fine to coarse sand (predominantly fine to medium grain), 5% non-plastic fines, strong hydrocarbon odor and discoloration	

Notes: Boring Log Reviewed By: M. Cutler 7/11/03



bgs = below ground surface
 AMSL = above mean sea level
 NA = not applicable
 NAD = North American Datum

SVP = Soil Vapor Probe
 VEW = Vapor Extraction Well
 ID = Internal Diameter
 PID = Photolionization Detector
 PVC = Poly Vinly Chloride (Schedule 40)

FOSTER WHEELER **ENVIRONMENTAL CORPORATION**

LOG OF BORING **43402-B33 (BS/BV-3)** (Sheet 2 of 2)

Client: SWDIV	Drilling Company: West Hazmat
Project: Continued Remediation of Multiple UST Sites	Drilling Method: Hollow-Stem Auger
Project Number: 1990.063D	Sampling Method: Continuous Core
Location: MCB Camp Pendleton	Borehole Diameter: 10 in. 0-30Ft.
Geologist: D. Dirkin	Northing: 2,071,765.00 Feet (NAD 83; NAVD 88)
Date Started: June 6, 2003	Easting: 6,207,078.00 Feet (NAD 83; NAVD 88)
Date Completed: June 6, 503	Ground Surface Elevation: 252.40 Feet AMSL
Total Depth: 30.0 Feet bgs	Top of Casing Elevation: 251.90 Feet AMSL

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
24.5		2" ID PVC Screen with 0.01-inch Slots			24.5	SP		POORLY GRADED SAND: dark greenish gray, moist, moderately dense, 95% fine to coarse sand (predominately fine to medium grain), 5% non-plastic fines, strong hydrocarbon odor and discoloration	230
25		Hydrated Bentonite Chips (1.5 cu ft)							
		2/16 Lonestar Sand (2.5 cu ft)							
26.5		2" ID PVC Screen with 0.01-inch Slots				ML		26.5 to 30 ft. SANDY SILT: dark greenish gray, wet, soft, moderate plasticity, 65% non-plastic fines, 25% fine to medium sand, 10% plastic fines, strong hydrocarbon odor and visible staining observed	225
30					0.6			Soil boring terminated by field geologist Groundwater encountered at approximately 24 feet bgs Biosparge/Blovent well installed in accordance with design specifications	220
35									215

Notes: Boring Log Reviewed By: M. Cutler 7/11/03

bgs = below ground surface
 AMSL = above mean sea level
 NA = not applicable
 NAD = North American Datum

SVP = Soil Vapor Probe
 VEW = Vapor Extraction Well
 ID = Internal Diameter
 PID = Photoionization Detector
 PVC = Poly Vinly Chloride (Schedule 40)

210620 SVE MULTI-COMPLETION WSS 063NEW-1.GPJ FSTRW SA.GDT 11/12/03



TETRA TECH FW, INC.

June 10, 2004

Monitoring Well Permit Clerk
Site Assessment and Mitigation Program
County of San Diego, Department of Environmental Health
P.O. Box 129261
San Diego, CA 92112-9261

**Subject: Groundwater Monitoring Well Installation, UST Site 43402, MCB
Camp Pendleton**

Reference: Permit LMON 102158

Well Permit Clerk:

Per your request, Tetra Tech FW, Inc. is submitting the attached document in fulfillment of the conditions of monitoring well construction permit number LMON 102158. The permit was issued on April 12, 2004 and the County was given 48 hours notice prior to commencement of the work. Three dual completion biovent wells were installed at the site on April 20, 2004. During the installation of the each well screen, the filter pack materials were surged into place by agitating the casings within the borehole.

Property Owner: United States Marine Corps
Site Address: UST Site 43402
43 Area, MCB Camp Pendleton, California 92055
Contact Person: Ms. Tracey Sahagun
RCRA Division Head

The attached documents include boring/biovent well logs with well construction information and volumes of materials used in the construction of each well, a signed



1940 E. Deere Avenue, Suite 200, Santa Ana, CA 92705
Tel 949.756.7500 Fax 949.756.7560

stamped Registered Geologist certification letter for the boring/biovent well logs, and a location map.

If you have any questions regarding this matter, please contact the undersigned.

Sincerely,

Tetra Tech FW, Inc.

A handwritten signature in black ink, appearing to read 'M Binkin', with a stylized flourish at the end.

Marianne Binkin
Project Geologist
760-430-0536

Attachments:

Copy of Permit

Location Map

Registered Geologist Certification Letter

Boring/Biovent Well Logs



PERMIT #LMON102158
A.P.N. #101-520-14-00
EST #H05939-059

**COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH
LAND AND WATER QUALITY DIVISION**

MONITORING WELL CONSTRUCTION PERMIT

SITE NAME: BUILDING 43402

SITE ADDRESS: MCB, CAMP PENDLETON, CA 92055

PERMIT TO: INSTALL 3 MULTI-SCREEN GROUNDWATERING MONITORING WELLS

PERMIT APPROVAL DATE: APRIL 12, 2004

PERMIT EXPIRES ON: AUGUST 10, 2004

RESPONSIBLE PARTY: MARINE CORPS BASE, CAMP PENDLETON

PERMIT CONDITIONS:

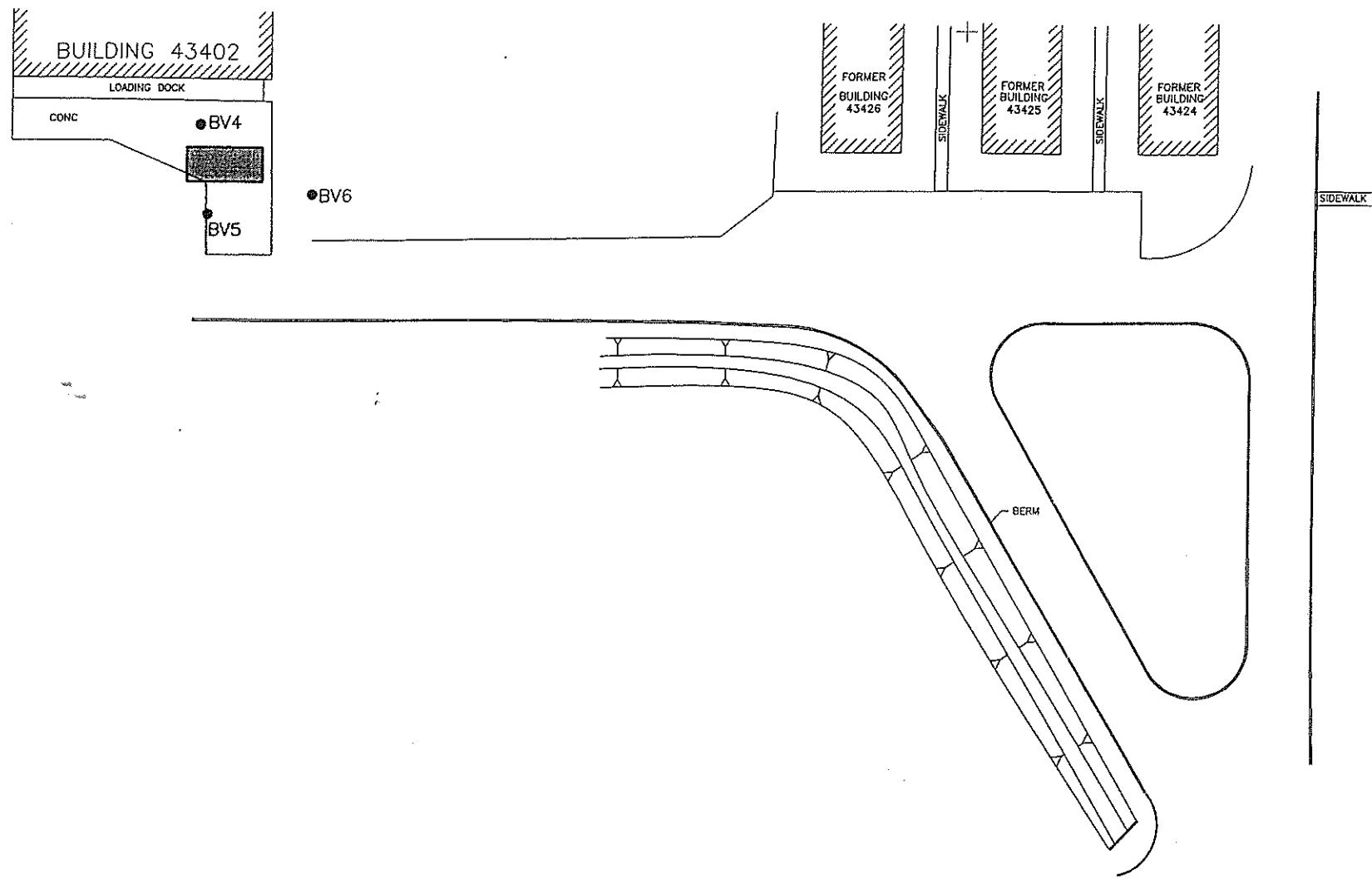
1. Multi-screen wells are approved as proposed, however since only one foot of filter pack is proposed above the perforations, wells should be surged to develop during construction to eliminate any bridging.
2. Contact the Regional Water Quality Control Board for their comments and concerns regarding the proposed activities.
3. Wells must have a minimum 3-foot concrete surface seal. The surface seal shall consist of concrete able to withstand the maximum anticipated load without cracking or deteriorating. The concrete should meet Class A specifications of a minimum 4000-pound compressive strength.
4. All water and soil resulting from the activities covered by this permit must be managed, stored and disposed of as specified in the SAM Manual in Section 5, E- 4: (http://www.sdcountry.ca.gov/deh/lwq/sam/manual_guidelines.html). In addition, drill cuttings must be properly handled and disposed in compliance with the Stormwater Best Management Practices of the local jurisdiction.
5. Within 60 days of completing work, submit a well construction report, including all well and/or boring logs and laboratory data to the Well Permit Desk. This report must include all items required by the SAM Manual, Section 5, Pages 6 & 7.
6. This office must be given 48-hour notice of any drilling activity on this site and advanced notification of drilling cancellation. Please contact the Well Permit Desk at 338-2339.

APPROVED BY: Carol Spangenberg
CAROL SPANGENBERG

DATE: 04/12/2004

NOTIFIED: J.M. msj 4/12/04 msj

DRAWN BY: MD	CHECKED BY: DD	APPROVED BY: MC	DCN: FWSO-RAC-04-0983	DRAWING NO: 04098321.DWG
DATE: 03/28/04	REV: REVISION 0		CTO: #0063	



LEGEND



-  APPROXIMATE LOCATION OF FORMER UNDERGROUND STORAGE TANK
-  BIOVENT WELL

Figure 2-1
LOCATION OF BIOVENT WELLS,
UST SITE 43402

MCB CAMP PENDLETON

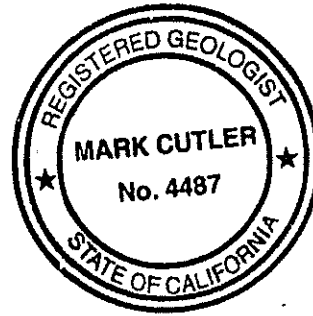

TETRA TECH FW, INC.

WELL CONSTRUCTION

Statement of Certification

I, Mark Cutler, certify that, to the best of my knowledge, the data and information presented in the boring logs listed below is accurate and complete. Field activities and documentation were performed in accordance with accepted practices and procedures.


Mark Cutler, CA RG # 4487



PERMIT NO. LMON 102158

MCB Camp Pendleton, 43 Area, UST Site 43402

- 43402-B34 (BV-4)
- 43402-B35 (BV-5)
- 43402-B36 (BV-6)

TETRA TECH FW, INC.

LOG OF BORING 43402-B34 (BV-4)

(Sheet 1 of 1)

NAVY SW DIV

Drilling Company: West Hazmat

Project: Remediation of Multiple UST Sites

Drilling Method: Hollow-Stem Auger

Project Number: 1990.063D

Sampling Method: Continuous Core

Location: MCB CAMP PENDLETON

Borehole Diameter: 8 in. 0-23Ft.

Geologist: D. Bertolacci

Northing: 2071789.4 (NAD83)

Date Started: April 20, 2004

Easting: 6207045.4 (NAD83)

Date Completed: April 20, 2004

Ground Surface Elevation: 252.4 AMSL (NAVD88)

Total Depth: 23.0 Feet bgs

Top of Casing Elevation: 251.9 AMSL (NAVD88)

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
5		Concrete (1.1 cubic feet)						8" concrete	250
		Bentonite grout (2.7 cubic feet)				ML		0.66 to 14 ft. SANDY SILT: dark brown, moist, moderately stiff to stiff 55% non-plastic fines, 35% fine to medium sand, 10% plastic fines, isolated clay stringers, occasional subangular fine gravel, no hydrocarbon odor or staining observed	245
15		Hydrated Bentonite Chips (.68 cubic feet)							240
		2/16 Lonestar Sand (1.2 cubic feet)							
		1-inch diameter 0.010" slotted PVC screen							
20		Hydrated Bentonite Chips (.68 cubic feet)				SM		14 to 23 ft. SILTY SAND: dark gray, moist, moderately dense, 60% fine to coarse subangular sand, 20% moderately stiff non-plastic fines, 10% plastic fines, 10% subangular fine gravel, strong hydrocarbon odor and staining observed	235
		2/16 Lonestar Sand (1.2 cubic feet)							
		1-inch diameter 0.010" slotted PVC screen							
25				0063-060 0063-061 0063-062				Soil boring terminated at 23 feet bgs. No groundwater encountered during drilling.	230
								Dual completion Biovent Well installed in accordance with design specifications.	225

Notes: Reviewed by M. Cutler on 6/9/2004

bgs = below ground surface

AMSL = above mean sea level

NAD 83 = North American Datum 1983

NAVD 88 = North American Vertical Datum 1988

PID = Photoionization Detector

PVC = Polyvinyl Chloride (Schedule 40)

TETRA TECH FW, INC.

LOG OF BORING 43402-B35 (BV-5) (Sheet 1 of 1)

Client: NAVY SW DIV

Drilling Company: West Hazmat

Project: Remediation of Multiple UST Sites

Drilling Method: Hollow-Stem Auger

Project Number: 1990.063D

Sampling Method: Continuous Core

Location: MCB CAMP PENDLETON

Borehole Diameter: 8 in. 0-24Ft.

Geologist: D. Bertolacci

Northing: 2071755.9 (NAD83)

Date Started: April 21, 2004

Easting: 6207048.1 (NAD83)

Date Completed: April 21, 2004

Ground Surface Elevation: 252.4 AMSL (NAVD88)

Total Depth: 24.0 Feet bgs

Top of Casing Elevation: 251.9 AMSL (NAVD88)

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
5		Concrete (1.1 cubic feet)						5" of concrete	250
		Bentonite grout (2.7 cubic feet)				ML		0.5 to 17 ft. SANDY SILT: dark brown, moist, moderately stiff, moderate plasticity, 60% non-plastic fines, 35% fine to medium sand, 5% plastic fines, no hydrocarbon odor or staining observed	245
15		Hydrated Bentonite Chips (.68 cubic feet)							240
		2/16 Lonestar Sand (1.2 cubic feet)						slight hydrocarbon odor from approximately 15 to 17 feet bgs	
		1-inch diameter 0.010" slotted PVC screen							
20		Hydrated Bentonite Chips (.68 cubic feet)	☒	0063-068		SM		17 to 24 ft. SILTY SAND: brown, moist, moderately dense, 60% fine to coarse subangular sand, 35% moderately stiff non-plastic fines, 5% subangular fine gravel, no hydrocarbon odor or staining observed	235
		2/16 Lonestar Sand (1.2 cubic feet)	☒	0063-069					
		1-inch diameter 0.010" slotted PVC screen	☒	0063-070					
			☒	0063-071					230
25								Soil boring terminated at 24 feet bgs. No groundwater encountered during drilling.	
								Dual completion Biovent Well installed in accordance with design specifications.	225

Notes: Reviewed by M. Cutler on 6/9/2004

bgs = below ground surface

AMSL = above mean sea level

NAD 83 = North American Datum 1983

NAVD 88 = North American Vertical Datum 1988

PID = Photoionization Detector

PVC = Polyvinyl Chloride (Schedule 40)

TETRA TECH FW, INC.

LOG OF BORING 43402-B36 (BV-6) (Sheet 1 of 1)

NAVY SW DIV

Drilling Company: West Hazmat

Project: Remediation of Multiple UST Sites

Drilling Method: Hollow-Stem Auger

Project Number: 1990.063D

Sampling Method: Continuous Core

Location: MCB CAMP PENDLETON

Borehole Diameter: 8 in. 0-23Ft.

Geologist: D. Bertolacci

Northing: 2071763.3 (NAD83)

Date Started: April 21, 2004

Easting: 6207087.1 (NAD83)

Date Completed: April 21, 2004

Ground Surface Elevation: 252.4 AMSL (NAVD88)

Total Depth: 23.0 Feet bgs

Top of Casing Elevation: 251.9 AMSL (NAVD88)

Depth (ft.)	Well/Boring Completion	Well/Boring Remarks	Samples	Sample ID	PID Results	USCS	Graphic Log	LITHOLOGIC DESCRIPTION	Elevation (ft.)
5		Concrete (1.1 cubic feet)						3" Asphalt Surface 1.5 ft. Fill with Gravel	250
		Bentonite grout (2.7 cubic feet)				ML		1.5 to 15.5 ft. SILT WITH SAND: dark brown, moist, moderately stiff, moderate plasticity, 75% non-plastic fines, 20% fine to medium sand, 5% plastic fines, no hydrocarbon odor or staining observed	245
15		Hydrated Bentonite Chips (.68 cubic feet)							240
		2/16 Lonestar Sand (1.2 cubic feet)							
		1-inch diameter 0.010" slotted PVC screen							
20		Hydrated Bentonite Chips (.68 cubic feet)				SM		15.5 to 23 ft. SILTY SAND WITH GRAVEL: brown to greyish brown, moist, loose, 50% fine to coarse subangular sand, 25% soft non-plastic fines, 25% subangular fine to coarse gravel, slight hydrocarbon odor and staining observed	235
		2/16 Lonestar Sand (1.2 cubic feet)							
		1-inch diameter 0.010" slotted PVC screen							
25								Soil boring terminated at 23 feet bgs. No groundwater encountered during drilling.	230
								Dual completion Biovent Well installed in accordance with design specifications.	225

Notes: Reviewed by M. Cutler on 6/9/2004

bgs = below ground surface

AMSL = above mean sea level

NAD 83 = North American Datum 1983

NAVD 88 = North American Vertical Datum 1988

PID = Photoionization Detector

PVC = Polyvinyl Chloride (Schedule 40)

ATTACHMENT 2
LABORATORY ANALYTICAL REPORTS

LABORATORY ANALYTICAL REPORT

**PROJECT UST Site 43402
Lab Project No. R04D0039**

Report Date: May 6 2003

Revision 0

Prepared For:

Sevda Aleckson
Foster Wheeler Environmental Corporation
1940 E. Deere Street
Santa Ana, CA 92705
Tel: (949) 756 – 7513
Fax: (949) 756 – 7560

CENTER FOR ENVIRONMENTAL MICROBIOLOGY

555 Technology Court, Suite 100, Riverside, CA 92507
Tel: (909) 788-0808; Fax: (909) 788-8011

May 6 2004

Project No. 1990.063D

Foster Wheeler Environmental Corporation
Attention: Dr. Jeff Oslick
1940 E. Deere Street
Santa Ana, CA 92705

Dear Sevda Aleckson:

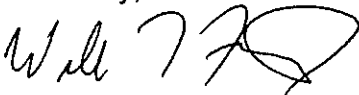
This report contains the test results for the soil/groundwater sample(s) from Project No. 1990.063D received under chain of custody by the Center for Environmental Microbiology (CEM) on April 20 2004. These samples are associated with our Laboratory Project No. R04D0039. Test results are based on analyses specified on the analytical report [following page(s)]. The original report for any subcontracted analysis is provided herein.

All applicable quality control procedures met laboratory-specified acceptance criteria. There were no deviations from the laboratory procedures.

This report may only be reproduced in full, with the written approval of CEM. This cover letter is an integral part of the analytical report.

If you have any questions, please feel free to call me at (909) 788-0808, or by e-mail at biocenter@biocem.com.

Sincerely,




William T. Frankenberger, Jr. Ph.D.
Laboratory Director

cc: Project File

CENTER FOR ENVIRONMENTAL MICROBIOLOGY

555 Technology Court, Suite 100, Riverside, CA 92507
Tel: (909) 788-0808; Fax: (909) 788-8011

Analytical Report

Client: Foster Wheeler Environmental Corp.	CEM Project Number: R04D0039
Project: 1990.063D	Date Sampled: 04/21/2004
Media: Bulk	Date Received: 04/21/2004
Media Type: Soil	Date Analyzed: 05/04/2004
	Analyst:  Scott Khoan

Client Sample Number (Lab Sample ID)	Analysis	Method	Reporting Limit	% Recovery	RPD	Result	Units
0063-062 (R04D0039-1)	Hydrocarbon Oxidizing Microbial Population	Proprietary	0.2x10 ¹	N/A	N/A	4.3x10 ¹	MPN/g
	Orthophosphate – Phosphorous	EPA 365.2	0.2	99.5	N/A	< 0.2	mg/Kg
	Ammonium – Nitrogen	EPA 350.2	5.0	N/A	1.95	10.2	mg/Kg
	Nitrate – Nitrogen	84-3.4.3.2 ⁽²⁾	0.5	N/A	1.44	10.4	mg/Kg

LEGEND

CFU - Colony Forming Units; MPN - Most Probable Number; g - gram; mg - milligrams; Kg - kilogram; mL - milliliters;
N/A - Not applicable; TNTC - Too Numerous to Count; OBSC - Obscured Colonies; RPD - Relative Percent Difference

Notes: ⁽¹⁾Subcontracted analysis

⁽²⁾Methods of Soil Analysis, Chemical and Microbiological Properties, 2nd Edition, 1986. Black. C.A.

These data are intended to be interpreted in conjunction with the information presented in the cover letter of this report.

CHAIN-OF-CUSTODY RECORD

PROJECT NAME		PURCHASE ORDER NO.		ANALYSES REQUIRED		LABORATORY NAME	
U.S. SITE 43402		020848 TASK 26				CEM	
PROJECT LOCATION		PROJECT NO.					
CAMP PENDLETON		1990-063D					
SAMPLER NAME		SAMPLER SIGNATURE					
M. BINKIN		M.B.					
PROJECT CONTACT		AIRBILL NUMBER					
SENDA AVELLON		VIA COURIER					
SAMPLE ID	DATE COLLECTED	TIME COLLECTED	NO. OF CONTAINER	T	A	T	COMMENTS
0063-062	4/24/91	1552	1	X			
0037-062	4/24/91	1552	1	X			
<p>Hydrocarbon Degradation</p> <p>MPN Method</p> <p>365.2 Orthophosphate</p> <p>353.2 Nitrate Nitrogen</p> <p>350.3 Ammonia</p>							
<p>LABORATORY ID (FOR LABORATORY)</p> <p>RO4D0039</p>							
<p>LABORATORY INSTRUCTIONS/COMMENTS</p> <p>NOTE HOLDING TIMES FOR ABOVE ANALYSES</p>							
<p>COMPOSITE DESCRIPTION</p>							
<p>SAMPLE CONDITION UPON RECEIPT (FOR LABORATORY)</p> <p>TEMPERATURE: <input type="checkbox"/> INTACT <input type="checkbox"/> BROKEN</p> <p>COOLER: <input type="checkbox"/> INTACT <input type="checkbox"/> BROKEN</p>							

LABORATORY ANALYTICAL REPORT

**PROJECT UST Site 43402
Lab Project No. R04D0041**

Report Date: May 6 2003

Revision 0

Prepared For:

Sevda Aleckson
Foster Wheeler Environmental Corporation
1940 E. Deere Street
Santa Ana, CA 92705
Tel: (949) 756 – 7513
Fax: (949) 756 – 7560

CENTER FOR ENVIRONMENTAL MICROBIOLOGY

555 Technology Court, Suite 100, Riverside, CA 92507
Tel: (909) 788-0808; Fax: (909) 788-8011

May 6 2004

Project No. 1990.063D

Foster Wheeler Environmental Corporation
Attention: Dr. Jeff Oslick
1940 E. Deere Street
Santa Ana, CA 92705

Dear Sevda Aleckson:

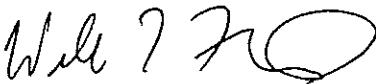
This report contains the test results for the soil/groundwater sample(s) from Project No. 1990.063D received under chain of custody by the Center for Environmental Microbiology (CEM) on April 21 2004. These samples are associated with our Laboratory Project No. R04D0041. Test results are based on analyses specified on the analytical report [following page(s)]. The original report for any subcontracted analysis is provided herein.

All applicable quality control procedures met laboratory-specified acceptance criteria. There were no deviations from the laboratory procedures.

This report may only be reproduced in full, with the written approval of CEM. This cover letter is an integral part of the analytical report.

If you have any questions, please feel free to call me at (909) 788-0808, or by e-mail at biocenter@biocem.com.

Sincerely,



William T. Frankenberger, Jr. Ph.D.
Laboratory Director

cc: Project File

CENTER FOR ENVIRONMENTAL MICROBIOLOGY

555 Technology Court, Suite 100, Riverside, CA 92507
Tel: (909) 788-0808; Fax: (909) 788-8011

Analytical Report

Client: Foster Wheeler Environmental Corp.	CEM Project Number: R04D0041
Project: 1990.063D	Date Sampled: 04/21/2004
Media: Bulk	Date Received: 04/21/2004
Media Type: Soil	Date Analyzed: 05/04/2004
	Analyst: Scott Khoan

Client Sample Number (Lab Sample ID)	Analysis	Method	Reporting Limit	% Recovery	RPD	Result	Units
0063-069 (R04D0041-1)	Hydrocarbon Oxidizing Microbial Population	Proprietary	0.2×10^1	N/A	N/A	7.4×10^0	MPN/g
	Orthophosphate – Phosphorous	EPA 365.2	0.2	N/A	N/A	< 0.2	mg/Kg
	Ammonium – Nitrogen	EPA 350.2	5.0	103	3.27	10.7	mg/Kg
	Nitrate – Nitrogen	84-3.4.3.2 ⁽²⁾	0.5	111	1.49	13.2	mg/Kg
0063-066 (R04D0041-2)	Hydrocarbon Oxidizing Microbial Population	Proprietary	0.2×10^1	N/A	N/A	6.7×10^1	MPN/g
	Orthophosphate – Phosphorous	EPA 365.2	0.2	N/A	N/A	< 0.2	mg/Kg
	Ammonium – Nitrogen	EPA 350.2	5.0	N/A	1.45	13.7	mg/Kg
	Nitrate – Nitrogen	84-3.4.3.2 ⁽²⁾	0.5	N/A	0.80	18.5	mg/Kg

LEGEND

CFU - Colony Forming Units; MPN - Most Probable Number; g - gram; mg - milligrams; Kg - kilogram; mL - milliliters;
N/A - Not applicable; TNTC - Too Numerous to Count; OBSC - Obscured Colonies; RPD - Relative Percent Difference

Notes: ⁽¹⁾Subcontracted analysis

⁽²⁾Methods of Soil Analysis, Chemical and Microbiological Properties, 2nd Edition, 1986. Black. C.A.

These data are intended to be interpreted in conjunction with the information presented in the cover letter of this report.

CHAIN-OF-CUSTODY RECORD

PROJECT NAME		PURCHASE ORDER NO.		ANALYSES REQUIRED		LABORATORY NAME	
PROJECT LOCATION		PROJECT NO.		TYP		COMMENTS	
SAMPLER NAME		SAMPLER SIGNATURE		LEVEL		LABORATORY	
PROJECT CONTACT		BILL NUMBER		NO. OF CONTAINER		ANALYSES REQUIRED	
SAMPLE ID		DATE COLLECTED		TIME COLLECTED		LABORATORY INSTRUCTIONS/COMMENTS	
SAMPLE ID		DATE COLLECTED		TIME COLLECTED		LABORATORY INSTRUCTIONS/COMMENTS	
00603-009	4/21/04	1527	1	3	4	X	EPA 350.3 as Nitrogen
00603-010	4/21/04	1015	1	3	4	X	EPA 350.3 as Nitrogen
<div> <div> RECEIVED BY (Signature) COMPANY </div> <div> RECEIVED BY (Signature) COMPANY </div> </div>							
<div> <div> RECEIVED BY (Signature) COMPANY </div> <div> RECEIVED BY (Signature) COMPANY </div> </div>							
<div> <div> RECEIVED BY (Signature) COMPANY </div> <div> RECEIVED BY (Signature) COMPANY </div> </div>							

CHAIN-OF-CUSTODY RECORD

[illegible]

White - Laboratory; Pink - Laboratory; Canary - Project File; Manila - Data Management

COPY

TABLE OF CONTENTS

CLIENT: TETRA TECH FW, INC.
PROJECT: CAMP PENDLETON, CTO 63, UST SITE 43402
SDG: 04D145

SECTION	PAGE
Cover Letter, COC/Sample Receipt Form	1000 – 1003
GC/MS-VOA **	2000 –
GC/MS-SVOA **	3000 –
GC-VOA **	4000 –
GC-SVOA METHOD 3550B/M8015	5000 – 5055
HPLC **	6000 –
METALS **	7000 –
WET **	8000 –
OTHERS **	9000 –

** - Not Requested

received
5/10/04



LABORATORIES, INC.

1835 W. 205th Street

Torrance, CA 90501

Tel: (310) 618-8889

Fax: (310) 618-0818

Date: 05-05-2004

EMAX Batch No.: 04D145

Attn: Sevda Aleckson

Tetra Tech FW, Inc.

1940 E Deere Ave, Suite 200

Santa Ana CA 92705

Subject: Laboratory Report

Project: Camp Pendleton, CTO 63,UST SITE 43402

Enclosed is the Laboratory report for samples received on
04/22/04. The data reported include :

Sample ID	Control #	Col Date	Matrix	Analysis
0063-060	D145-01	04/20/04	SOIL	TPH DIESEL
0063-067	D145-02	04/21/04	SOIL	TPH DIESEL
0063-070	D145-03	04/21/04	SOIL	TPH DIESEL
0063-071	D145-04	04/21/04	SOIL	TPH DIESEL

The results are summarized on the following pages.

Please feel free to call if you have any questions concerning
these results.

Sincerely yours,

Kam Y. Pang, Ph.D.
Laboratory Director

UNF/ FOSTER WHEELER ENVIRONMENTAL CORPORATION
2320 Columbia Street, Suite 640 San Diego, CA 92101 (619) 234-8696

NUMBER
06555

06565
04b145

CHAIN-OF-CUSTODY RECORD

[illegible]

White - Laboratory; Pink - Laboratory; Pink - Project File; Canary - Project File; Canary - Data Management

SAMPLE RECEIPT FORM 1

Type of Delivery	Delivered By/Airbill	ECN	04D145
<input checked="" type="checkbox"/> EMAX Courier	SEE P.P.P.	Receipient	SITNIKOV
<input type="checkbox"/> Client Delivery		Date	04.22.04.
<input type="checkbox"/> Third Party		Time	14:35

COC Inspection		
<input checked="" type="checkbox"/> Client Name	<input checked="" type="checkbox"/> Sampler Name	<input checked="" type="checkbox"/> Sampling Date/Time/Location
<input checked="" type="checkbox"/> Address	<input checked="" type="checkbox"/> Courier Signature/Date/Time	<input checked="" type="checkbox"/> Analysis Required
<input checked="" type="checkbox"/> Client PM/FC	<input checked="" type="checkbox"/> TAT	<input checked="" type="checkbox"/> Matrix
<input checked="" type="checkbox"/> Tel #/Fax #	<input checked="" type="checkbox"/> Sample ID	<input type="checkbox"/> Preservative (if any)
Safety Issues	<input checked="" type="checkbox"/> None	<input type="checkbox"/> Superfund Site Samples
Comments:	<input type="checkbox"/> High Concentrations expected	
	<input type="checkbox"/> Rad Screening Required	

Packaging Inspection			
Container	<input checked="" type="checkbox"/> Cooler <i>ONE</i>	<input type="checkbox"/> Box	<input type="checkbox"/>
Condition	<input checked="" type="checkbox"/> Custody Seal	<input checked="" type="checkbox"/> Intact	<input type="checkbox"/> Damaged
Packaging	<input type="checkbox"/> Bubble Pack	<input type="checkbox"/> Styrofoam	<input checked="" type="checkbox"/> Sufficient
Temperatures	<input checked="" type="checkbox"/> Cooler 1 <i>2.5°C</i>	<input checked="" type="checkbox"/> Cooler 2 _____	<input type="checkbox"/> Cooler 3 _____
	<input type="checkbox"/> Cooler 5 _____	<input type="checkbox"/> Cooler 6 _____	<input type="checkbox"/> Cooler 7 _____
	<input type="checkbox"/> Cooler 9 _____	<input type="checkbox"/> Cooler 10 _____	<input type="checkbox"/> Cooler 11 _____
			<input type="checkbox"/> Cooler 12 _____

☒ *PLASTIC BAGS*

Comments: _____

[illegible]

LSCID : Lab Sample Container ID

REVIEWS

Sample Labeling

Date _____

SRF

Date _____

PM

Date _____

1002

REPORTING CONVENTIONS

DATA QUALIFIERS:

Lab Qualifier	AFCEE Qualifier	Description
J	F	Indicates that the analyte is positively identified and the result is less than RL but greater than MDL.
N		Indicates presumptive evidence of a compound.
B	B	Indicates that the analyte is found in the associated method blank as well as in the sample at above QC level.
E	J	Indicates that the result is above the maximum calibration range.
*	*	Out of QC limit.

Note: The above qualifiers are used to flag the results unless the project requires a different set of qualification criteria.

ACRONYMS AND ABBREVIATIONS:

CRDL	Contract Required Detection Limit
RL	Reporting Limit
MRL	Method Reporting Limit
PQL	Practical Quantitation Limit
MDL	Method Detection Limit
DO	Diluted out

DATES

The date and time information for leaching and preparation reflect the beginning date and time of the procedure unless the method, protocol, or project specifically requires otherwise.

LABORATORY REPORT FOR

TETRA TECH FW, INC.

CAMP PENDLETON, CTO 63

METHOD 3550B/M8015
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

SDG#: 04D145

5000

CASE NARRATIVE

CLIENT: TETRA TECH FW, INC.
PROJECT: CAMP PENDLETON, CTO 63
SDG: 04D145

METHOD 3550B/M8015
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

Four (4) soil samples were received on 04/22/04 for Total Petroleum Hydrocarbons by Extraction by Method 3550B/M8015 in accordance with SW846 3RD Edition.

1. Holding Time

Analytical holding time was met. Extraction was performed and completed on 04/23/04.

2. Calibration

Initial calibration was seven points for Diesel. %RSDs were within 20%. Continuing calibrations were carried out at 12-hour intervals and all recoveries were within 85-115%.

3. Method Blank

Method blank was free of contamination at half of the reporting limit.

4. Surrogate Recovery

Surrogate recovery in samples D145-01 and -02 were diluted out. All other recoveries were within QC limits.

5. Lab Control Sample/Lab Control Sample Duplicate

All recoveries were within QC limits.

6. Matrix Spike/Matrix Spike Duplicate

No sample was spiked.

7. Sample Analysis

Samples were analyzed according to the prescribed QC procedures. All criteria were met with the aforementioned exception. Samples were quantitated from C10 to C24 using Diesel (C10-C24) calibration factor. Samples D145-01 and -02 displayed diesel-like fuel pattern.

LAB CHRONICLE
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

Client : TETRA TECH FW, INC.
Project : CAMP PENDLETON, CTO 63
SDG NO. : 040145
Instrument ID :

Client Sample ID	Laboratory Sample ID	Dilution Factor	% Moist	Analysis Date/Time	Extraction Date/Time	Sample Data FN	Calibration Prep. Data FN	Batch	Notes
MBLK1S	DSD027S8	1	NA	04/25/0406:21	04/23/0411:30	TD22081A	TD22070A	DSD027S	Method Blank
LCS1S	DSD027SL	1	NA	04/25/0404:57	04/23/0411:30	TD22079A	TD22070A	DSD027S	Lab Control Sample (LCS)
LCD1S	DSD027SC	1	NA	04/25/0405:39	04/23/0411:30	TD22080A	TD22070A	DSD027S	LCS Duplicate
0063-060	D145-01T	50	14.5	04/29/0400:48	04/23/0411:30	TD28017A	TD28015A	DSD027S	Diluted Sample
0063-067	D145-02T	10	4.0	04/29/0401:30	04/23/0411:30	TD28018A	TD28015A	DSD027S	Diluted Sample
0063-070	D145-03W	1	10.5	04/29/0400:06	04/23/0411:30	TD28016A	TD28015A	DSD027S	Field Sample
0063-071	D145-04	1	20.1	04/25/0409:08	04/23/0411:30	TD22085A	TD22070A	DSD027S	Field Sample

FN - Filename
% Moist - Percent Moisture

5002

SAMPLE RESULTS

5003

METHOD 3550B/8015B
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

```

=====
Client      : TETRA TECH FW, INC.      Date Collected: 04/20/04
Project     : CAMP PENDLETON, CTO 63   Date Received: 04/22/04
Batch No.   : 04D145                   Date Extracted: 04/23/04 11:30
Sample ID: 0063-060                     Date Analyzed: 04/29/04 00:48
Lab Samp ID: 0145-01T                    Dilution Factor: 50
Lab File ID: TD28017A                     Matrix      : SOIL
Ext Btch ID: DS0027S                       % Moisture   : 14.5 /
Calib. Ref.: TD28015A                     Instrument ID : GCT050
=====

```

PARAMETERS	RESULTS (mg/kg)	RL (mg/kg)	MDL (mg/kg)
DIESEL	28000	580	170

SURROGATE PARAMETERS	% RECOVERY	QC LIMIT
HEXACOSANE	DO	65-135

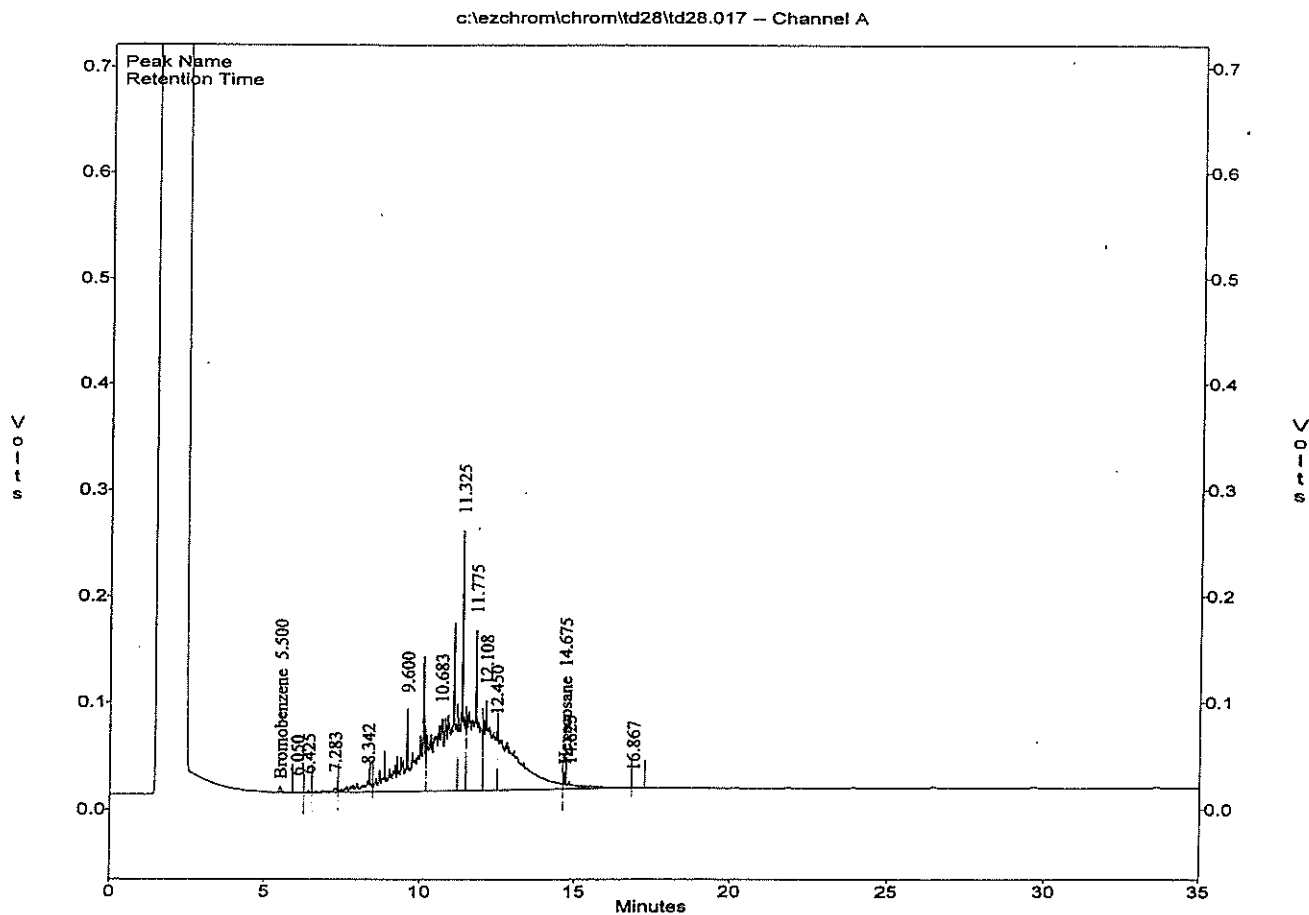
RL : Reporting Limit
 SUR1 : Hexacosane
 Parameter : H-C Range
 Diesel : C10-C24
 DO : Diluted out

METHOD 8015 by GC/FID
EMAX Analytical Laboratories, Inc.

File : c:\ezchrom\chrom\td28\td28.017
Method : c:\ezchrom\methods\ds50d08.met
Sample ID : 04D145-01T .02/1ML
Acquired : Apr 29, 2004 00:48:23
Printed : Apr 29, 2004 09:21:05
User : LUCY

Channel A Results

#	Peak Name	Ret.Time (Min)	Area	Ave. CF	ESTD Conc. (ppm)
1	Bromobenzene	5.500	34678	14621.9	2.4
12	Hexacosane	14.675	47568	35420.3	1.3
G1	Diesel (TOTAL)		13652978	29434.8	463.8
G2	Diesel (C10-C24)		13409918	28488.6	470.7
G3	Diesel (C10-C28)		13637941	28524.7	478.1



5005
4/29/04

METHOD 3550B/8015B
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

```
=====
Client   : TETRA TECH FW, INC.      Date Collected: 04/21/04
Project  : CAMP PENDLETON, CTO 63   Date Received: 04/22/04
Batch No. : 040145                  Date Extracted: 04/23/04 11:30
Sample ID: 0063-067                 Date Analyzed: 04/29/04 01:30
Lab Samp ID: D145-02T                Dilution Factor: 10
Lab File ID: TD28018A                Matrix       : SOIL
Ext Btch ID: DSD027S                 % Moisture    : 4.0
Calib. Ref.: TD28015A                Instrument ID : GCT050
=====
```

PARAMETERS	RESULTS (mg/kg)	RL (mg/kg)	MDL (mg/kg)
DIESEL	6700	100	29

SURROGATE PARAMETERS	% RECOVERY	QC LIMIT
HEXACOSANE	DO	65-135

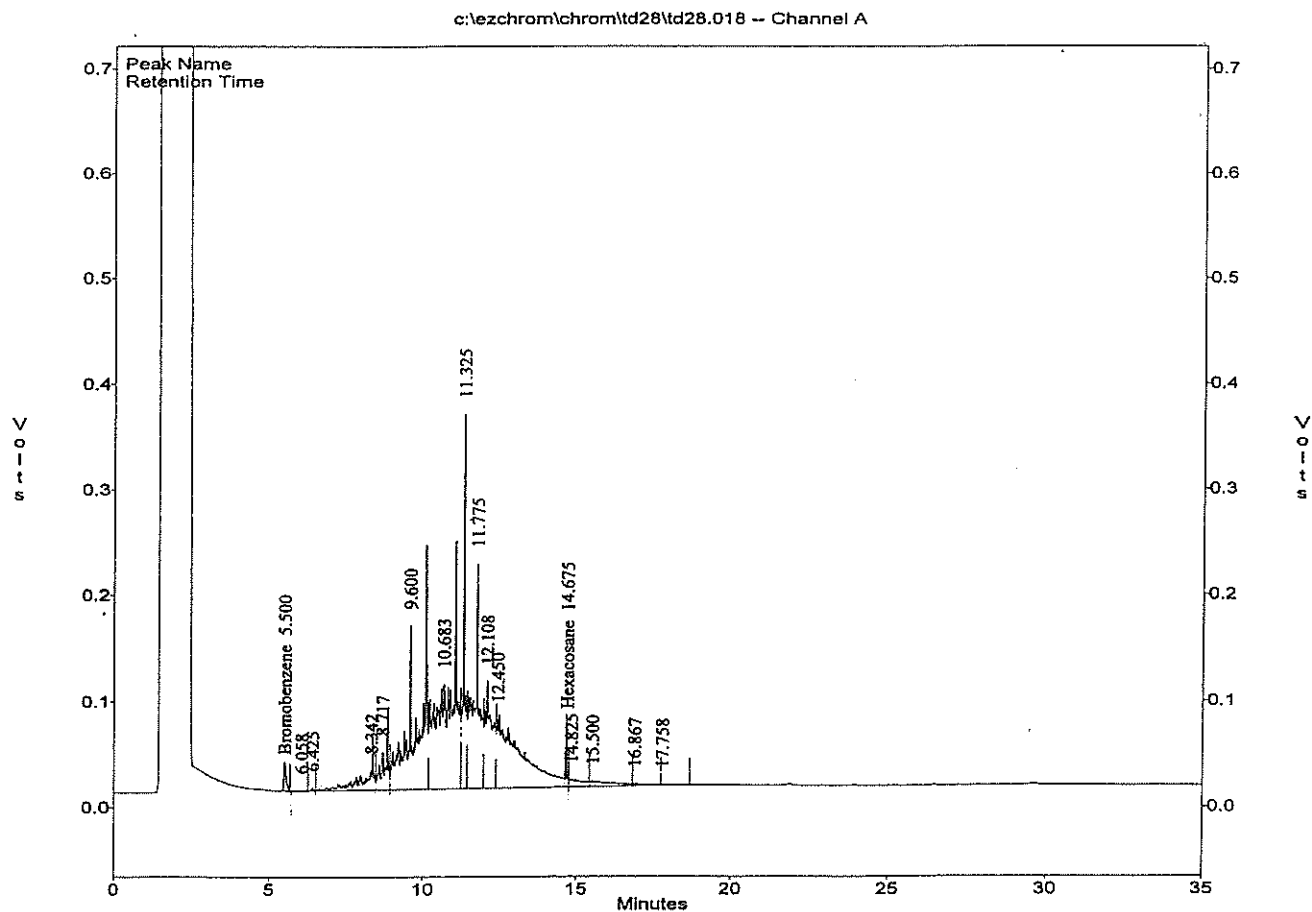
RL : Reporting Limit
SUR1 : Hexacosane
Parameter H-C Range
Diesel C10-C24
DO : Diluted out

METHOD 8015 by GC/FID
EMAX Analytical Laboratories, Inc.

File : c:\ezchrom\chrom\td28\td28.018
Method : c:\ezchrom\methods\ds50d08.met
Sample ID : 04D145-02T .1/1ML
Acquired : Apr 29, 2004 01:30:20
Printed : Apr 29, 2004 09:22:10
User : LUCY

Channel A Results

#	Peak Name	Ret.Time (Min)	Area	Ave. CF	ESTD Conc. (ppm)
1	Bromobenzene	5.500	129910	14621.9	8.9
12	Hexacosane	14.675	138267	35420.3	3.9
G1	Diesel (TOTAL)		18991952	29434.8	645.2
G2	Diesel (C10-C24)		18437200	28488.6	647.2
G3	Diesel (C10-C28)		18899020	28524.7	662.5



5007
AS 4/29/04

METHOD 3550B/8015B
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

```

=====
Client      : TETRA TECH FW, INC.      Date Collected: 04/21/04
Project     : CAMP PENDLETON, CTO 63   Date Received: 04/22/04
Batch No.   : 040145                   Date Extracted: 04/23/04 11:30
Sample ID   : 0063-070                 Date Analyzed: 04/29/04 00:06
Lab Samp ID : 0145-03W                  Dilution Factor: 1
Lab File ID : TD28016A                  Matrix      : SOIL
Ext Btch ID : DSD027S                   % Moisture   : 10.5
Calib. Ref. : TD28015A                  Instrument ID : GCT050
=====

```

PARAMETERS	RESULTS (mg/kg)	RL (mg/kg)	MDL (mg/kg)
DIESEL	ND	11	3.2

SURROGATE PARAMETERS	% RECOVERY	QC LIMIT
HEXACOSANE	95	65-135

RL : Reporting Limit
 SUR1 : Hexacosane
 Parameter H-C Range
 Diesel C10-C24

P
.
C

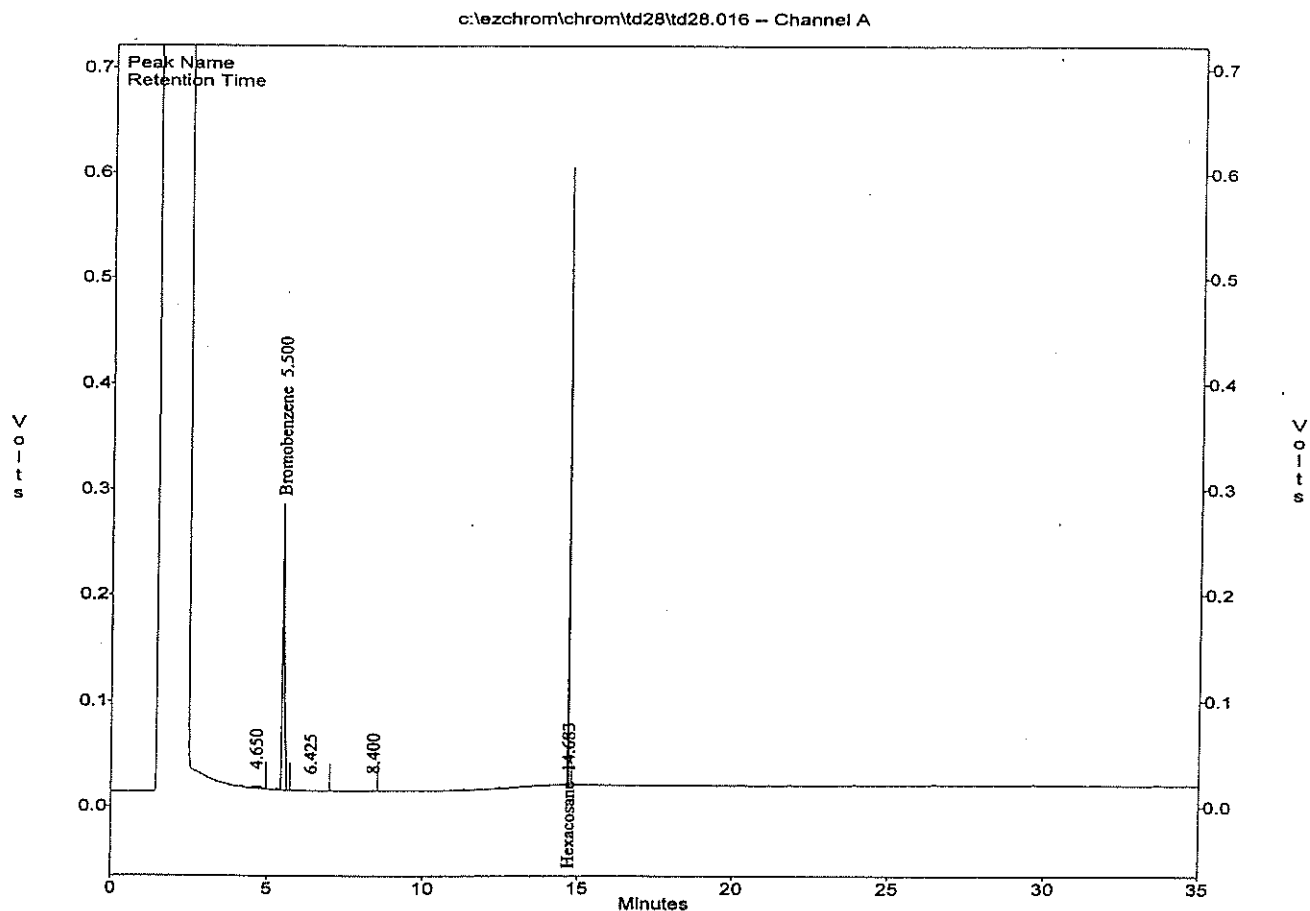
5008

METHOD 8015 by GC/FID
EMAX Analytical Laboratories, Inc.

File : c:\ezchrom\chrom\td28\td28.016
Method : c:\ezchrom\methods\ds50d08.met
Sample ID : 04D145-03W
Acquired : Apr 29, 2004 00:06:27
Printed : Apr 29, 2004 09:15:10
User : LUCY

Channel A Results

#	Peak Name	Ret.Time (Min)	Area	Ave. CF	ESTD Conc. (ppm)
2	Bromobenzene	5.500	1279868	14621.9	87.5
5	Hexacosane	14.683	837202	35420.3	23.6
G1	Diesel (TOTAL)		46862	29434.8	1.6
G2	Diesel (C10-C24)		9031	28488.6	0.3
G3	Diesel (C10-C28)		9031	28524.7	0.3



5069
4/29/04

METHOD 3550B/8015B
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

```
=====
Client      : TETRA TECH FW, INC.      Date Collected: 04/21/04
Project     : CAMP PENDLETON, CTO 63   Date Received: 04/22/04
Patch No.   : 04D145                   Date Extracted: 04/23/04 11:30
Sample ID   : 0063-071                  Date Analyzed: 04/25/04 09:08
Lab Samp ID : D145-04                   Dilution Factor: 1
Lab File ID : TD22085A                  Matrix       : SOIL
Ext Btch ID : DSD027S                   % Moisture    : 20.1
Calib. Ref. : TD22070A                  Instrument ID : GCT050
=====
```

PARAMETERS	RESULTS (mg/kg)	RL (mg/kg)	MDL (mg/kg)
DIESEL	ND	13	3.5

SURROGATE PARAMETERS	% RECOVERY	QC LIMIT
HEXACOSANE	100	65-135

RL : Reporting Limit
SUR1 : Hexacosane
Parameter H-C Range
Diesel C10-C24

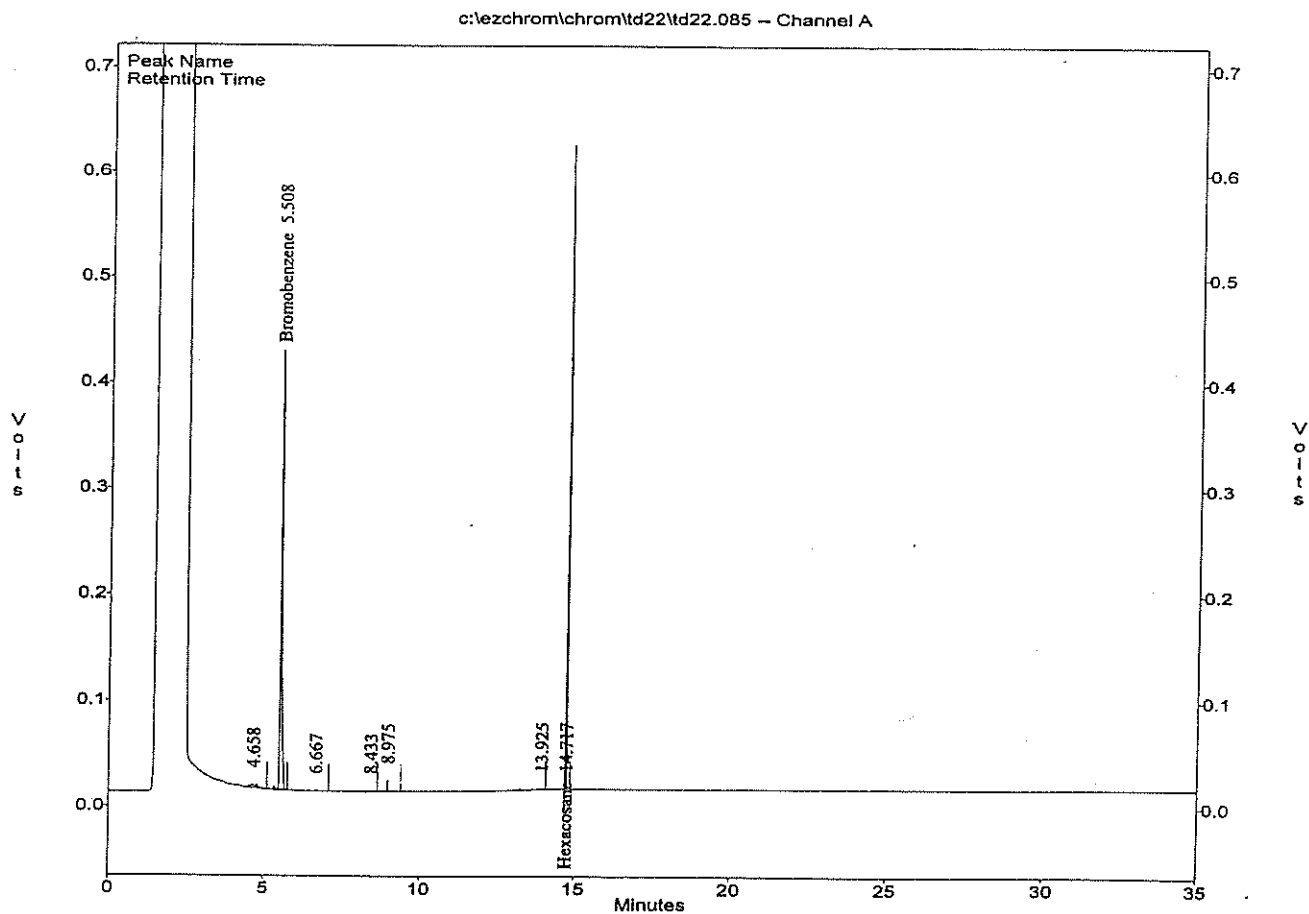
b
s
s

METHOD 8015 by GC/FID
EMAX Analytical Laboratories, Inc.

File : c:\ezchrom\chrom\td22\td22.085
Method : c:\ezchrom\methods\ds50d08.met
Sample ID : 04D145-04
Acquired : Apr 25, 2004 09:08:15
Printed : Apr 26, 2004 15:38:30
User : CALVIN

Channel A Results

#	Peak Name	Ret.Time (Min)	Area	Ave. CF	ESTD Conc. (ppm)
2	Bromobenzene	5.508	1398401	14621.9	95.6
7	Hexacosane	14.717	882429	35420.3	24.9
G1	Diesel (TOTAL)		73045	29434.8	2.5
G2	Diesel (C10-C24)		28075	28488.6	1.0
G3	Diesel (C10-C28)		28075	28524.7	1.0



5011

4/26/04

QC SUMMARIES

METHOD 3550B/8015B
TOTAL PETROLEUM HYDROCARBONS BY EXTRACTION

```

=====
Client      : TETRA TECH FW, INC.      Date Collected: NA
Project     : CAMP PENDLETON, CTO 63   Date Received: 04/23/04
Batch No.   : 040145                  Date Extracted: 04/23/04 11:30
Sample ID   : MBLK1S                  Date Analyzed: 04/25/04 06:21
Lab Samp ID : DSD027SB                Dilution Factor: 1
Lab File ID : TD22081A                Matrix      : SOIL ✓
Ext Btch ID : DSD027S                % Moisture   : NA
Calib. Ref. : TD22070A                Instrument ID : GCT050
=====
  
```

PARAMETERS	RESULTS (mg/kg)	RL (mg/kg)	MDL (mg/kg)
DIESEL	ND	10	2.8
SURROGATE PARAMETERS			
	% RECOVERY	QC LIMIT	
HEXACOSANE	104	65-135	

RL : Reporting Limit
 SUR1 : Hexacosane
 Parameter H-C Range
 Diesel C10-C24

EMAX QUALITY CONTROL DATA
 LCS/LCD ANALYSIS

 CLIENT: TETRA TECH FW, INC.
 PROJECT: CAMP PENDLETON, CTO 63
 BATCH NO.: 04D145
 METHOD: METHOD 3550B/8015B

 =====
 MATRIX: SOIL % MOISTURE: NA
 DILUTION FACTOR: 1 1
 SAMPLE ID: MBLK1S
 LAB SAMP ID: DSD027SB DSD027SL DSD027SC
 LAB FILE ID: TD22081A TD22079A TD22080A
 DATE EXTRACTED: 04/23/0411:30 04/23/0411:30 04/23/0411:30 DATE COLLECTED: NA
 DATE ANALYZED: 04/25/0406:21 04/25/0404:57 04/25/0405:39 DATE RECEIVED: 04/23/04
 PREP. BATCH: DSD027S DSD027S DSD027S
 CALIB. REF: TD22070A TD22070A ✓ TD22070A ✓

ACCESSION:

PARAMETER	BLNK RSLT (mg/kg)	SPIKE AMT (mg/kg)	BS RSLT (mg/kg)	BS % REC	SPIKE AMT (mg/kg)	BSD RSLT (mg/kg)	BSD % REC	RPD (%)	QC LIMIT (%)	MAX RPD (%)
Diesel	ND	500	537	107	500	555	111	3	55-145	30

 =====

SURROGATE PARAMETER	SPIKE AMT (mg/kg)	BS RSLT (mg/kg)	BS % REC	SPIKE AMT (mg/kg)	BSD RSLT (mg/kg)	BSD % REC	QC LIMIT (%)
Hexacosane	25	26.9	108	25	27.5	110	65-135

5014

APPENDIX B

NATURAL ATTENUATION MODELING

**Naval Facilities Engineering Command, Southwest
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, CA 92132-5190**

**CONTRACT NO. N68711-04-D-1104
CTO No. 0004**

APPENDIX B

FINAL

NATURAL ATTENUATION MODELING FOR UNDERGROUND STORAGE TANK SITE 43402

**Revision 1
September 26, 2005**

**MARINE CORPS BASE
CAMP PENDLETON, CALIFORNIA**

DCN: SES-TECH-05-0126

Prepared by:

SES-TECH

**18000 International Boulevard, Suite 1009
Seattle, WA 98188**

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1.3 MODEL CONSTRUCTION	1-2
1.3.1 Input Parameters.....	1-2
1.3.2 Solution and Results.....	1-6
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ATTACHMENTS

Exhibit A BIOSCREEN Input Interface

LIST OF FIGURES

- Figure 1-1 Groundwater Flow Direction and Source Zone Map
- Figure 1-2 Model Results for TPH-d Along Plume Centerline
(Year 7 of 100-Year Simulation Period)

ABBREVIATIONS AND ACRONYMS

CAP	Corrective Action Plan
cm/sec	centimeters per second
EPA	U.S. Environmental Protection Agency
ft/ft	feet per foot
g/cc	grams per cubic centimeter
kg/L	kilograms per liter
L/kg	liters per kilogram
MCB	Marine Corps Base
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL/g	milliliters per gram
NAPL	non-aqueous phase liquid
RNA	remediation through natural attenuation
TPH-d	total petroleum hydrocarbons quantified as diesel
UST	Underground Storage Tank
WQO	Water Quality Objective

1.0 INTRODUCTION

Contaminant transport analytical modeling was used to evaluate and predict the effectiveness of biological and physical processes in reducing residual contaminant concentrations in groundwater at Underground Storage Tank (UST) Site 43402, Marine Corps Base (MCB) Camp Pendleton. The modeling was performed to evaluate if total petroleum hydrocarbons quantified as diesel (TPH-d), detected above its secondary taste and odor Water Quality Objective (WQO), will degrade within a reasonable time frame. The maximum concentration for TPH-d detected during the most recent groundwater monitoring event was used as the starting concentration input to the model. The following sections provide a discussion of the model, input parameters, modeling scenarios, and modeling results.

1.1 CONCEPTUAL MODEL

Since diesel fuel consists of a multitude of chemicals, in order to model TPH-d degradation in groundwater, naphthalene, which is a common constituent of diesel, was conservatively selected as a proxy for TPH-d. Of the listed representative components of diesel (Chevron Oil, 2004), only three compounds, naphthalene, anthracene, and biphenyl, are listed in the U. S. Environmental Protection Agency (EPA) Preliminary Remedial Goals (PRGs) Table (EPA, 2004). A comparison of the toxicity of these three compounds indicates that naphthalene has the lowest PRG concentrations. For example, the PRG values (in tap water) for naphthalene, biphenyl, and anthracene, are 6.2, 300, and 1,800 µg/L, respectively. Furthermore, a comparison of their organic carbon-water partition coefficient values (K_{oc}) shows that naphthalene has the lowest value, and thus will travel the fastest in groundwater among the 3 compounds. The K_{oc} values for naphthalene, biphenyl, and anthracene, are 1,200, 7,800, and 24,000, respectively. Therefore, because of the relative rate of transport and the relative toxicity of naphthalene, it is used as the most conservative choice as a proxy for modeling the fate-and-transport of diesel fuel in groundwater.

Based on the geologic and hydrogeologic description presented in previous reports, the geologic conditions of the aquifer materials where the groundwater plume is located can be reasonably conceptualized as a homogeneous system for the purposes of evaluating the effectiveness of natural attenuation in reducing the concentration of TPH-d (modeled as naphthalene). Therefore, for all practical purposes of subject modeling, the aquifer is modeled as a single layer consisting of silty sands.

1.2 MODEL SELECTION

The U.S. Environmental Protection Agency (EPA) BIOSCREEN Natural Attenuation Decision Support System (EPA, 1996) is an analytical model that simulates remediation through natural

attenuation (RNA) of dissolved hydrocarbons at petroleum fuel release sites. The software, programmed in the Microsoft Excel spreadsheet environment and based on the Domenico analytical solute transport model, has the ability to simulate advection, dispersion, adsorption, and aerobic decay that have been shown to be the primary biodegradation processes at many petroleum release sites. BIOSCREEN includes three different model types:

1. Solute transport without decay
2. Solute transport with biodegradation modeled as a first-order decay process
3. Solute transport with biodegradation modeled as an 'instantaneous' reaction

The model is designed to simulate biodegradation by both aerobic and anaerobic reactions. It was developed for the Air Force Center for Environmental Excellence Technology Transfer Division at Brooks Air Force Base by Groundwater Services, Inc., Houston, Texas.

The site was modeled using the Type 2 BIOSCREEN model to predict how far TPH-d (modeled as naphthalene) could migrate before attenuating to levels below the secondary taste and odor water quality objective (0.1 milligrams per liter (mg/L)). The Type 1 and Type 3 BIOSCREEN models were not used because these models assume that the compound will readily biodegrade, and naphthalene is not considered readily biodegradable.

The model was used to predict TPH-d concentrations (modeled as naphthalene) over distance, and the results were compared to the groundwater secondary taste and odor WQO for diesel (0.1 mg/L).

1.3 MODEL CONSTRUCTION

1.3.1 Input Parameters

Model input parameters were based on pertinent past and recent field measurements, as well as literature. Input parameters for the BIOSCREEN model are presented below.

Seepage Velocity

The seepage velocity is the interstitial groundwater velocity, equaling Darcy velocity divided by effective porosity. Seepage velocity is calculated by multiplying hydraulic conductivity by hydraulic gradient and dividing by effective porosity. Hydraulic conductivity, hydraulic gradient, and effective porosity values were input to BIOSCREEN to calculate seepage velocity as listed below:

- Typical hydraulic conductivity values in the BIOSCREEN help system for silty soils range from 1×10^{-5} to 1×10^{-3} centimeters per second (cm/sec). Model input hydraulic conductivity of 1×10^{-3} cm/sec was chosen.

- A hydraulic gradient value of 0.02 feet per foot (ft/ft) based on recent groundwater level measurements was used.
- Effective porosity of 30 percent (assumed value) was used.

Dispersivity

Dispersion refers to the process whereby a dissolved contaminant will be spatially distributed. Dispersivity values were based on the dispersivity estimation calculations provided in the BIOSCREEN input interface.

- Longitudinal dispersivity = $3.28 * 0.83 [\log (\text{plume length} / 3.28)]^{2.414}$
- Transverse dispersivity = $0.10 * \text{longitudinal dispersivity}$
- Vertical dispersivity = 0 feet (conservative)

Site data:

The plume length is estimated at approximately 200 feet. Therefore:

- Longitudinal dispersivity = 11 feet
- Transverse dispersivity = 1.1 feet
- Vertical dispersivity = 0 feet (conservative)

Adsorption/Retardation Factors

Adsorption to the soil matrix can reduce the concentration of dissolved contaminants moving through groundwater. The retardation factor is the ratio of the groundwater seepage velocity to the rate that organic chemicals migrate in the groundwater. The degree of retardation depends on both aquifer and constituent properties. The retardation factor is calculated using the following equation:

$$R = 1 + (K_d \rho_b) / n$$

Where:

- R = retardation factor,
- K_d = distribution coefficient = K_{oc} * f_{oc}
- K_{oc} = organic carbon-water partition coefficient
- f_{oc} = fraction organic carbon
- ρ_b = bulk density
- n = effective porosity

The K_{oc} value, expressed in milligrams per kilogram (mg/kg), mg/L, liters per kilogram (L/kg), or milliliters per gram (mL/g), is the chemical-specific partition coefficient between soil organic carbon and the aqueous phase. Larger values indicate greater affinity of contaminants for the

organic carbon fraction of soil. For naphthalene, a Koc value of 1,200 L/kg was input (EPA, 1987).

The foc value, which is unitless, is the fraction of the aquifer soil matrix comprised of natural organic carbon in uncontaminated areas. More natural organic carbon means more adsorption of organic constituents on the aquifer matrix. Based on site-specific soil testing, a foc value of 0.0013 was selected [Table 2-4 in the Corrective Action Plan (CAP)].

The ρ_b value [expressed in kilograms per liter (kg/L) or grams per cubic centimeter (g/cc)] of the aquifer matrix is related to porosity and pure solids density. Based on site-specific soil testing, a ρ_b value of 1.71 g/cc was selected (Table 2-3 in the CAP).

As described in the Seepage Velocity section discussion above, the model input 'n' value (porosity) is estimated at 30 percent.

First-order Decay Model

In BIOSCREEN, the first-order decay model assumes that the rate of biodegradation depends on the concentration of the contaminant and the rate coefficient.

A field half-life period ranging from 1 day to 258 days is reported for naphthalene (Tabak et al., 1981). However, in order to conservatively estimate the model predicted concentration at the compliance point, for naphthalene (TPH-d), a highly conservative half-life period of 4 years was chosen for the BIOSCREEN model input.

Source Zone Concentrations and Dimensions

Source zone concentration, expressed in mg/L, are aqueous phase concentrations in the source area. The source term corresponds to a vertical source plane, normal to the direction of groundwater flow, located at the downgradient limit of the area serving as the principal source of contaminant release to the groundwater.

BIOSCREEN allows up to five partitions of the source zone with different concentrations to account for spatial variations in the source zone.

The source zone was constructed with a width of 25 feet, consisting of one partition of uniform concentration of 0.5 mg/L TPH-d (modeled as naphthalene) (maximum TPH-d concentration detected during January 2005 sampling event).

Source Thickness In Saturated Zone

The source thickness in the saturated zone (Z) is the thickness in feet of contamination in the source zone. A Z value equal to 5 feet was input.

Mass of Contaminant in Source Zone (M_0)

M_0 is the summation of the mass of TPH-d (modeled as naphthalene) in the source zone in the following phases:

- Dissolved in groundwater
- Groundwater contamination adsorbed to soil
- As non-aqueous phase liquid (NAPL)

The source zone was conservatively conceptualized as 35 feet (length, L), by 25 feet (width, W) by, 5 feet thick (height, Z). The source zone was assumed to have a uniform, dissolved concentration in groundwater equal to the concentration of 0.5 mg/L; secondly, an equilibrium partitioning calculation was performed to calculate the mass of TPH-d (modeled as naphthalene) adsorbed to soil from groundwater. Thirdly, NAPL was assumed to be zero since free product is not present at the site. The results of the mass calculations of TPH-d (modeled as naphthalene) in its three phases are tabularized below:

Concentration	Mass of dissolved-phase TPH-d	Mass of adsorbed-phase TPH-d	Mass of NAPL TPH-d
C_{max}	$= C_{max} \times LWZ \times n$	$= K_d \times C_{max} \times LWZ \times (1-n) \times \rho_{soil}$	None
0.5 mg/L	0.019 kg	0.11499 kg	
Total M_0 TPH-d			0.134 kg

Notes:

mg/L – milligrams per liter

ρ_{soil} – density of soil particles = 1.7 g/cc

C_{max} – maximum concentration in $\mu\text{g/L}$

foc – fraction of organic carbon = 0.0013

K_d – soil distribution coefficient for naphthalene = $foc \times K_{oc}$ (organic carbon partitioning coefficient for naphthalene)

kg – kilogram

K_{oc} – 1200 L/kg

L – length of source zone = 35 feet

n – porosity = 0.30

W – width of source zone = 25 feet

Source Half-life

It is assumed that TPH-d (modeled as naphthalene) in the source zone attenuates primarily by the passing of fresh groundwater through the source zone (advection) and by biodegradation. The TPH-d (modeled as naphthalene) mass flux out due to advection is approximated as the groundwater flow through the source zone multiplied by the source concentration; the TPH-d (modeled as naphthalene) mass flux out due to biodegradation is approximated similarly as the

groundwater flow through the source zone multiplied by the biodegradation capacity of the water expressed in units of TPH-d (modeled as naphthalene) concentration.

With the first-order decay model, the biodegradation capacity is assumed to equal zero at the source. The algorithm then involves integrating the concentration versus time relationship (first-order decay) and using the relationship that the mass in the source zone over time is proportional to the source concentration over time. This yields the following expression for the half-life of the concentration of dissolved organics in the source zone:

$$t_{\text{half-source}} = (0.693 * M_0) / (Q * C_0)$$

Where:

$t_{\text{half-source}}$	=	Half-life of source concentration
Q	=	Groundwater flow through source zone = seepage velocity x cross sectional area of source zone
C_0	=	Effective source zone concentration (observed concentration + biodegradation capacity for instantaneous reaction assumption) at $t = 0$
M_0	=	Mass of dissolvable organics in source zone at $t = 0$

The algorithm for finding the half-life of the source zone for the first-order decay model is incorporated into BIOSCREEN (EPA, 1996).

Model Area Length and Width

The length and width of the model area are the extent of the site downgradient of the source zone at which the model predicts the concentration profile of TPH-d. The model input is 1,600 feet for length and 100 feet for width.

Simulation Time

The simulation time is the length of time for which concentrations are to be calculated. Model input is 100 years.

The source zone and groundwater flow direction are shown in Figure 1-1. The BIOSCREEN input interface is shown in Exhibit A.

1.3.2 Solution and Results

The solute-transport-with-first-order-biological-decay model (Type 2 model) showed that TPH-d (modeled as naphthalene) would attenuate to levels below the secondary taste and odor WQO (0.1 mg/L) within approximately 7 years and not migrate more than 50 feet downgradient of the source along the plume centerline (Figure 1-2). Thus, TPH-d (modeled as naphthalene) is clearly not predicted to reach the nearest groundwater supply well located over 3 miles from the site.

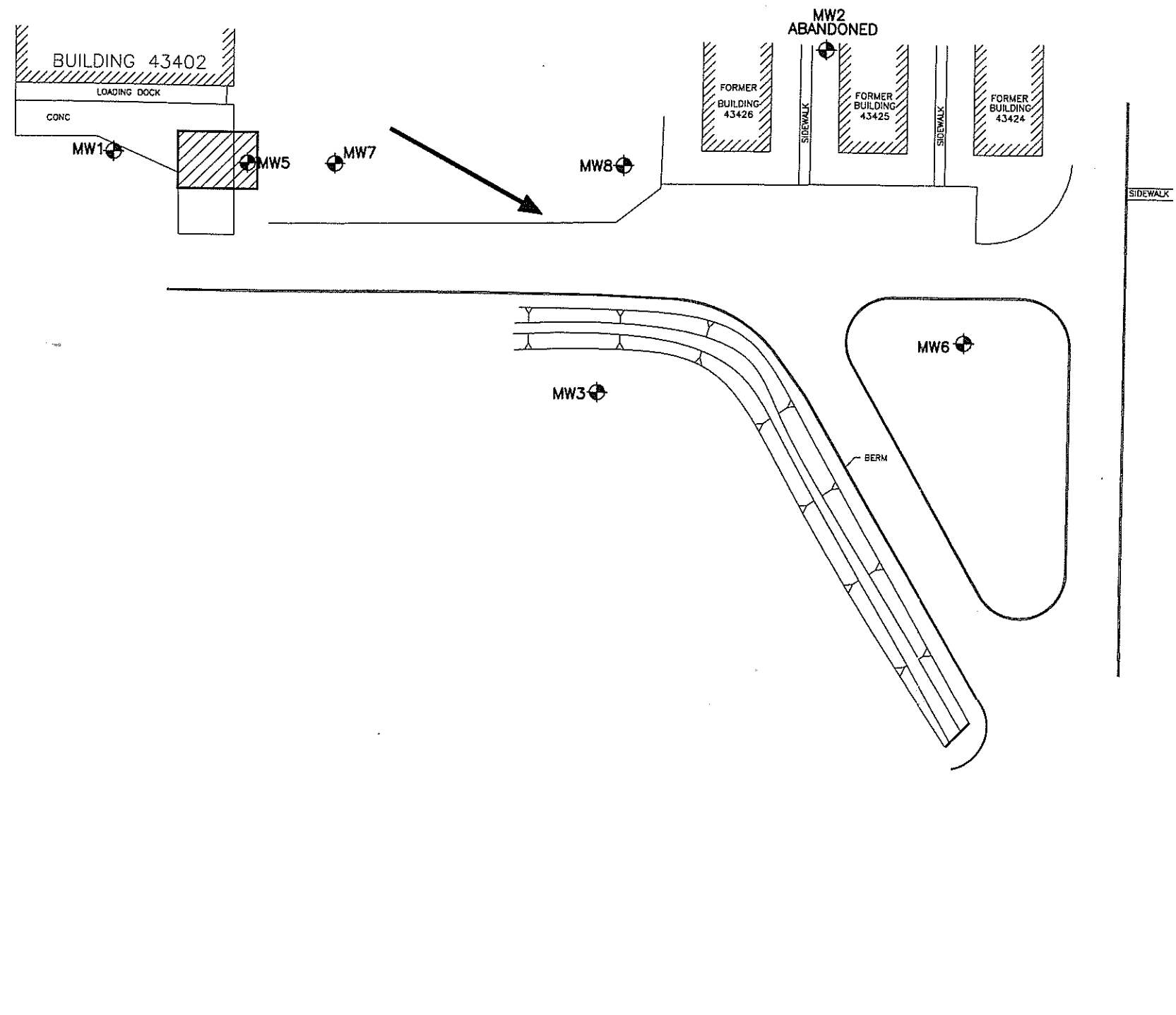
Using this model, the attenuating mechanisms are adsorption, dispersion, advection, and first-order biological decay.

2.0 REFERENCES




- Chevron Oil. 2004. Representative components of Diesel. Available at http://www.chevron.com/prodserv/fuels/bulletin/diesel/12_4_6_fs.htm.
- Tabak, H.H., S.A. Quave, C.I. Mashni, and E.F. Barth, 1981. *Biodegradability studies with organic priority pollutant compounds*. J. Water Poll. Control Fed. 53, 1503-1518.
- United States Environmental Protection Agency (EPA). 1987. *Superfund Public Health Evaluation Manual*. Office of Emergency and Remedial Response. EPA/540/1-86/060. Available at: http://www.epa.gov/earth1r6/6sf/sfsites/calcasieu_march_2003/table51.pdf.
- _____. 1996. *BIOSCREEN, Natural Attenuation Decision Support System User's Manual, Version 1.3*. Office of Research and Development: Washington, D.C. August.
- _____. 2004. *Region 9 Preliminary Remediation Goals Table 2004 Update*. October.

FIGURES

DRAWN BY: MD	CHECKED BY: SP	APPROVED BY: MC	DCN: SES-TECH-05-0126	DRAWING NO: 0501261-1.DWG
DATE: 09/19/05	REV: REVISION 0		CTO: #0004	



LEGEND

- MW6  MONITORING WELL ID
-  GROUNDWATER FLOW DIRECTION
-  MODELED SOURCE ZONE

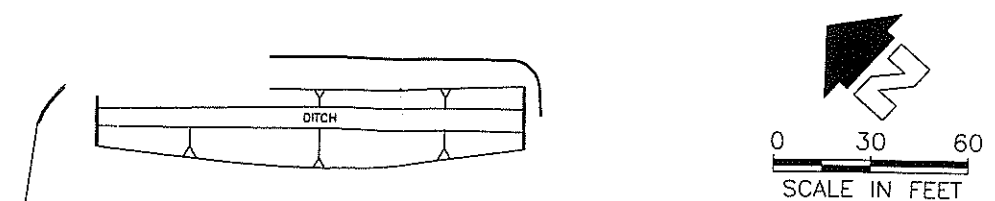


Figure 1-1
GROUNDWATER FLOW DIRECTION AND
SOURCE ZONE MAP

MCB CAMP PENDLETON

SES-TECH

FIGURE 1-2

MODEL RESULTS FOR TPH-D ALONG PLUME CENTERLINE
(YEAR 7 OF 100-YEAR SIMULATION PERIOD)

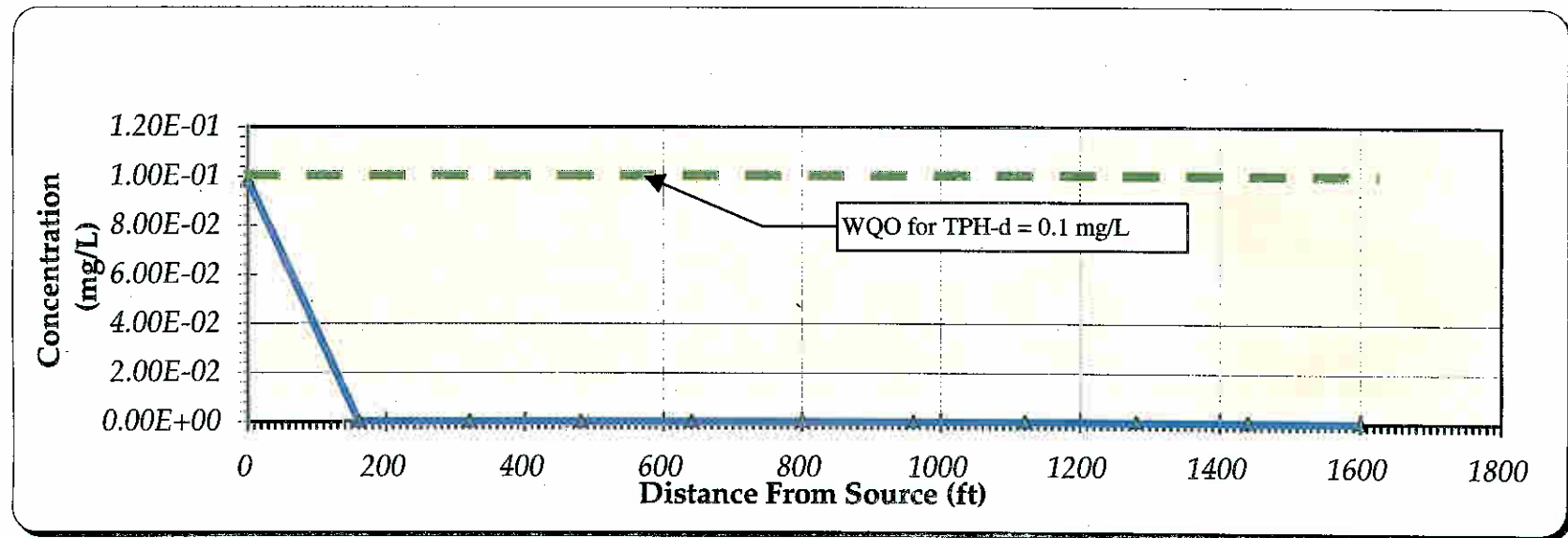


EXHIBIT A

BIOSCREEN INPUT INTERFACE

EXHIBIT A

BIOSCREEN INPUT INTERFACE

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence Version 1.4

List Site 43402
 MOB Camp Pendleton
 Run Name

1. HYDROGEOLOGY

Seepage Velocity*	Vs	<div><div></div></div> 58.6	(ft/yr)	
or		<div><div></div></div>		
Hydraulic Conductivity	K	<div><div></div></div> 1.0E-03	(cm/sec)	
Hydraulic Gradient	i	<div><div></div></div> 0.017	(ft/ft)	
Porosity	n	<div><div></div></div> 0.3	(-)	

2. DISPERSION

Longitudinal Dispersivity*	alpha x	<div><div></div></div> 11.0	(ft)	
Transverse Dispersivity*	alpha y	<div><div></div></div> 1.1	(ft)	
Vertical Dispersivity*	alpha z	<div><div></div></div> 0.0	(ft)	
or		<div><div></div></div>		
Estimated Plume Length	Lp	<div><div></div></div> 200	(ft)	

3. ADSORPTION

Retardation Factor*	Rf	<div><div></div></div> 9.9	(-)	
or		<div><div></div></div>		
Soil Bulk Density	rho	<div><div></div></div> 1.71	(kg/l)	
Partition Coefficient	Koc	<div><div></div></div> 1200	(L/kg)	
Fraction Organic Carbon	foc	<div><div></div></div> 1.3E-3	(-)	

4. BIODEGRADATION


1st Order Decay Coeff.*	lambda	<div><div></div></div> 1.7E-1	(per yr)	
or		<div><div></div></div>		
Solute Half-Life	t-half	<div><div></div></div> 4.00	(year)	

or Instantaneous Reaction Model

Delta Oxygen*	DO	<div><div></div></div>	(mg/L)	
Delta Nitrate*	NO3	<div><div></div></div>	(mg/L)	
Observed Ferrous Iron*	Fe2+	<div><div></div></div>	(mg/L)	
Delta Sulfate*	SO4	<div><div></div></div>	(mg/L)	
Observed Methane*	CH4	<div><div></div></div>	(mg/L)	

5. GENERAL

Modeled Area Length*		<div><div></div></div> 1600	(ft)	
Modeled Area Width*		<div><div></div></div> 100	(ft)	
Simulation Time*		<div><div></div></div> 100	(yr)	




6. SOURCE DATA

Source Thickness in Sat.Zone* 5 (ft)

Source Zones:

Width* (ft)	Cone. (mg/L)*	
<div><div></div></div> 0	<div><div></div></div> 0	1
<div><div></div></div> 0	<div><div></div></div> 0	2
<div><div></div></div> 25	<div><div></div></div> 0.5	3
<div><div></div></div> 0	<div><div></div></div> 0	4
<div><div></div></div> 0	<div><div></div></div> 0	5

Source Halflife (see Help):
 3 3 (yr)
Inst. React. 1st Order
Soluble Mass 0.13400 (Kg)
In Source NAPL Soil



Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)																			
Dist. from Source (ft)																			

8. CHOOSE TYPE OF OUTPUT TO SEE

RUN CENTERLINE

View Output

RUN ARRAY

View Output

Help

Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

APPENDIX C

**VERIFICATION SOIL BORING PERMIT,
AND LABORATORY ANALYTICAL REPORTS**



PERMIT #LMON102872
A.P.N. #101-530-15-00
EST #H95939-059

COUNTY OF SAN DIEGO
DEPARTMENT OF ENVIRONMENTAL HEALTH
LAND AND WATER QUALITY DIVISION

MONITORING WELL PERMIT EXTENSION

SITE NAME: AREA 43, SITE 43402

SITE ADDRESS: MARINE CORPS BASE, CAMP PENDLETON, CA 92055

PERMIT FOR: **2 SOIL BORINGS**

ORIGINAL EXPIRATION DATE: JUNE 4, 2005

THIS WELL PERMIT HAS BEEN EXTENDED AT THE REQUEST OF THE PERMITEE. ALL CONDITIONS ON THE ORIGINAL OR MODIFIED PERMIT ARE STILL IN EFFECT.

REQUEST RECEIVED: MAY 31, 2005

NEW EXPIRATION DATE: OCTOBER 2, 2005

APPROVED BY: _____

M. Crystal

DATE: 06/01/2005

NOTIFIED: _____

V.M. MSG 6/2/05 MSC

SES-TECH

September 20, 2005

Monitoring Well Permit Clerk
Site Assessment and Mitigation Program
County of San Diego, Department of Environmental Health
P.O. Box 129261
San Diego, CA 92112-9261

**Subject: Permit Completion Notification, UST Site 43402, Marine Corps Base (MCB)
Camp Pendleton, California**

Reference: Permit No. LMON 102872

Well Permit Clerk:

Per your request, SES-TECH is submitting the this letter in fulfillment of the conditions of boring permit number LMON 102872, originally issued on February 4, 2005 and extended on May 31, 2005. The work was conducted for the following project:

Property Owner: United States Marine Corps
Site Address: UST Site 43402
43 Area, MCB Camp Pendleton, California 92055
Contact Person: Mr. Chet Storrs
Remediation Branch Manager

On July 6, 2005, two direct push soil borings, VSB1 and VSB2, were advance to a total depth of 22 and 23 feet bgs. Following sample collection each boring was backfilled with approximately 0.4 cubic feet if bentonite grout, the surfaces were then completed with concrete (VSB 1) and asphalt (VSB 2) to match existing conditions. No soil logs were completed for these borings, as there were no soil cuttings recovered, a boring location map has been attached.

If you have any questions regarding this matter, please contact the undersigned.

Sincerely,
SES-TECH

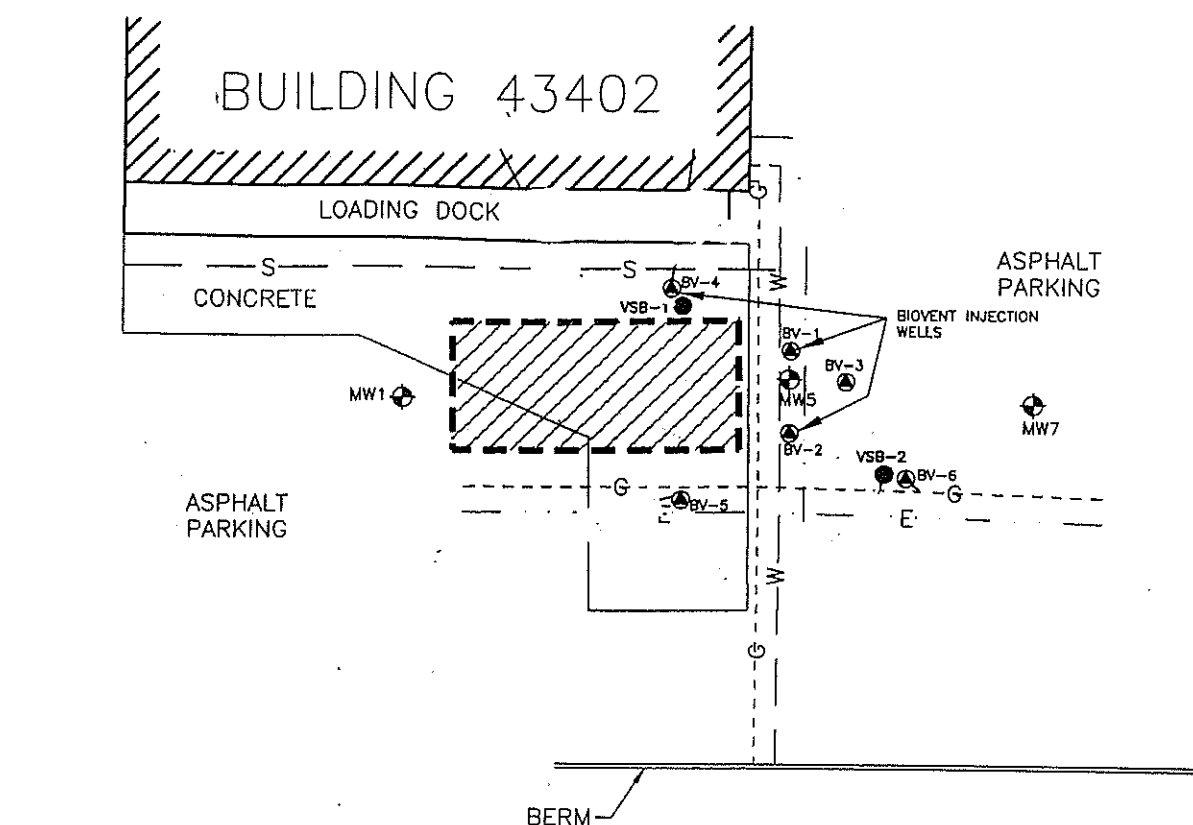


Mark Cutler, P.G., C.H.G.
Project Manger



Attachments:
Boring Location Map

DRAWING NO: 050126211.DWG	
DCN: SES-TECH-05-0126	CTO: #0004
APPROVED BY: MC	REV: REVISION 0
CHECKED BY: MC	
DRAWN BY: MD	DATE: 08/19/05



LEGEND

VSB-1 ●	VERIFICATION SOIL BORING
	AREA OF SOIL EXCAVATION
--W-G-S-E--	UNDERGROUND WATER, SEWER, ELECTRIC, GAS
⊕	GROUNDWATER MONITORING WELL
⊙	BIOVENT WELL
B-4 ⊙	LOCATION OF 1998 SITE ASSESSEMENT SOIL BORING
TPH-d	TOTAL PETROLEUM HYDROCARBONS AS DIESEL
ND	NOT DETECTED
mg/kg	MILLIGRAMS PER KILOGRAM
ft	FEET
J	ESTIMATED VALUE

Figure 2-11

SOIL BORINGS

UST SITE 43402, MCB CAMP PENDLETON

SES-TECH



NUMBER 12421

12421

[illegible]

White - Laboratory; Pink - Laboratory; Canary - Project File; Manila - Data Management

Applied P & CH Laboratories

13760 Magnolia Ave., Chino, CA 91710

Tel: (909) 590-1828 Fax: (909) 590-1498

Submitted to:
Tetra Tech EC, Inc.
Attention: Sveda Aleckson
1940 E. Deere Ave. Ste. 200
Santa Ana CA 92705
Tel: (949) 756-7500 Fax: (949) 756-7583

APCL Analytical Report

Service ID #: 801-053299
Collected by: Tamia T.K.
Collected on: 07/06/05
Received: 07/06/05
Extracted: 07/07-20/05
Tested: 07/07-21/05
Revised: 08/29/05
Sample Description: Soil from Camp Pendleton
Project Description: 1990.081E UST Site 43402

Analysis of Soil Samples

Component Analyzed	Method	Unit	PQL	Analysis Result 0081-080 05-03299-1
MOISTURE	ASTM-D2216	%Moisture	0.5	15
Dilution Factor				10
DIESEL (C10-C24)	8015B	mg/kg	10	3,700
Dilution Factor				20
SPLP DIESEL (C10-C24)	8015B	mg/L	0.1	60
VOLATILE ORGANICS				
Dilution Factor				100 (a)
ACETONE	8260B	µg/kg	50	< 5900
BENZENE	8260B	µg/kg	5	< 590
BROMODICHLOROMETHANE	8260B	µg/kg	5	< 590
BROMOFORM	8260B	µg/kg	5	< 590
BROMOMETHANE	8260B	µg/kg	5	< 590
METHYL ETHYL KETONE (MEK)	8260B	µg/kg	50	< 5900
CARBON TETRACHLORIDE	8260B	µg/kg	5	< 590
CHLOROBENZENE	8260B	µg/kg	5	< 590
CHLORODIBROMOMETHANE	8260B	µg/kg	5	< 590
CHLOROETHANE	8260B	µg/kg	5	< 590
CHLOROFORM	8260B	µg/kg	5	< 590
CHLOROMETHANE	8260B	µg/kg	5	< 590
1,1-DICHLOROETHANE	8260B	µg/kg	5	< 590
1,2-DICHLOROETHANE	8260B	µg/kg	5	< 590
1,1-DICHLOROETHENE	8260B	µg/kg	5	< 590
CIS-1,2-DICHLOROETHENE	8260B	µg/kg	5	< 590
TRANS-1,2-DICHLOROETHENE	8260B	µg/kg	5	< 590
1,2-DICHLOROPROPANE	8260B	µg/kg	5	< 590
CIS-1,3-DICHLOROPROPENE	8260B	µg/kg	5	< 590
TRANS-1,3-DICHLOROPROPENE	8260B	µg/kg	5	< 590
ETHYLBENZENE	8260B	µg/kg	5	< 590
2-HEXANONE	8260B	µg/kg	50	< 5900
METHYLENE CHLORIDE	8260B	µg/kg	5	96J
4-METHYL-2-PENTANONE (MIBK)	8260B	µg/kg	50	< 5900
METHYL-T-BUTYL ETHER (MTBE)	8260B	µg/kg	10	< 1200
STYRENE	8260B	µg/kg	5	< 590
1,1,2,2-TETRACHLOROETHANE	8260B	µg/kg	5	< 590
TETRACHLOROETHENE	8260B	µg/kg	5	< 590
TOLUENE	8260B	µg/kg	5	< 590
1,1,1-TRICHLOROETHANE	8260B	µg/kg	5	< 590
1,1,2-TRICHLOROETHANE	8260B	µg/kg	5	< 590
TRICHLOROETHENE	8260B	µg/kg	5	< 590
VINYL ACETATE	8260B	µg/kg	50	< 5900
VINYL CHLORIDE	8260B	µg/kg	5	< 590
XYLENES (TOTAL)	8260B	µg/kg	15	< 1800
TERT-BUTYL ALCOHOL (TBA)	8260B	µg/kg	50	< 5900
DIISOPROPYL ETHER (DIPE)	8260B	µg/kg	5	< 590
ETHYL TERT-BUTYL ETHER (ETBE)	8260B	µg/kg	5	< 590
TERT-AMYL METHYL ETHER (TAME)	8260B	µg/kg	5	< 590

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Component Analyzed	Method	Unit	PQL	Analysis Result	
				0081-080	
				05-03299-1	
SPLP VOLATILE ORGANICS					
Dilution Factor				1	
ACETONE	8260B	µg/L	50	< 50	
BENZENE	8260B	µg/L	0.5	< 0.5	
BROMODICHLOROMETHANE	8260B	µg/L	5	< 5	
BROMOFORM	8260B	µg/L	5	< 5	
BROMOMETHANE	8260B	µg/L	5	< 5	
METHYL ETHYL KETONE (MEK)	8260B	µg/L	50	< 50	
CARBON TETRACHLORIDE	8260B	µg/L	0.5	< 0.5	
CHLOROBENZENE	8260B	µg/L	5	< 5	
CHLORODIBROMOMETHANE	8260B	µg/L	5	< 5	
CHLOROETHANE	8260B	µg/L	5	< 5	
CHLOROFORM	8260B	µg/L	5	< 5	
CHLOROMETHANE	8260B	µg/L	5	< 5	
1,1-DICHLOROETHANE	8260B	µg/L	5	< 5	
1,2-DICHLOROETHANE	8260B	µg/L	0.5	< 0.5	
1,1-DICHLOROETHENE	8260B	µg/L	5	< 5	
CIS-1,2-DICHLOROETHENE	8260B	µg/L	5	< 5	
TRANS-1,2-DICHLOROETHENE	8260B	µg/L	5	< 5	
1,2-DICHLOROPROPANE	8260B	µg/L	5	< 5	
CIS-1,3-DICHLOROPROPENE	8260B	µg/L	0.5	< 0.5	
TRANS-1,3-DICHLOROPROPENE	8260B	µg/L	0.5	< 0.5	
ETHYLBENZENE	8260B	µg/L	0.5	< 0.5	
2-HEXANONE	8260B	µg/L	50	< 50	
METHYLENE CHLORIDE	8260B	µg/L	5	1J	
4-METHYL-2-PENTANONE (MIBK)	8260B	µg/L	50	< 50	
METHYL-T-BUTYL ETHER (MTBE)	8260B	µg/L	1	< 1	
STYRENE	8260B	µg/L	5	< 5	
1,1,2,2-TETRACHLOROETHANE	8260B	µg/L	1	< 1	
TETRACHLOROETHENE	8260B	µg/L	5	< 5	
TOLUENE	8260B	µg/L	0.65 ^(b)	< 0.65	
1,1,1-TRICHLOROETHANE	8260B	µg/L	5	< 5	
1,1,2-TRICHLOROETHANE	8260B	µg/L	5	< 5	
TRICHLOROETHENE	8260B	µg/L	5	< 5	
VINYL ACETATE	8260B	µg/L	50	< 50	
VINYL CHLORIDE	8260B	µg/L	0.5	< 0.5	
XYLENES (TOTAL)	8260B	µg/L	5	< 5	
TERT-BUTYL ALCOHOL (TBA)	8260B	µg/L	20	< 20	
DIISOPROPYL ETHER (DIPE)	8260B	µg/L	5	< 5	
ETHYL TERT-BUTYL ETHER (ETBE)	8260B	µg/L	5	< 5	
TERT-AMYL METHYL ETHER (TAME)	8260B	µg/L	5	< 5	

APCL Analytical Report

Component Analyzed	Method	Unit	PQL	Analysis Result 0081-080 05-03299-1
PAH				
Dilution Factor				1000 (a)
ACENAPHTHENE	8270-SIM	µg/kg	5	< 5900
ACENAPHTHYLENE	8270-SIM	µg/kg	5	< 5900
ANTHRACENE	8270-SIM	µg/kg	5	< 5900
BENZO(A)ANTHRACENE	8270-SIM	µg/kg	5	< 5900
BENZO(A)PYRENE	8270-SIM	µg/kg	5	< 5900
BENZO(B)FLUORANTHENE	8270-SIM	µg/kg	5	< 5900
BENZO(G,H,I)PERYLENE	8270-SIM	µg/kg	5	< 5900
BENZO(K)FLUORANTHENE	8270-SIM	µg/kg	5	< 5900
CHRYSENE	8270-SIM	µg/kg	5	< 5900
FLUORANTHENE	8270-SIM	µg/kg	5	< 5900
FLUORENE	8270-SIM	µg/kg	5	< 5900
INDENO(1,2,3-C,D)PYRENE	8270-SIM	µg/kg	5	< 5900
2-METHYLNAPHTHALENE	8270-SIM	µg/kg	5	< 5900
NAPHTHALENE	8270-SIM	µg/kg	5	< 5900
PHENANTHRENE	8270-SIM	µg/kg	5	< 5900
PYRENE	8270-SIM	µg/kg	5	< 5900
SPLP PAH				
Dilution Factor				100 (a)
ACENAPHTHENE	8270-SIM	µg/L	0.2	< 20
ACENAPHTHYLENE	8270-SIM	µg/L	0.2	< 20
ANTHRACENE	8270-SIM	µg/L	0.2	< 20
BENZO(A)ANTHRACENE	8270-SIM	µg/L	0.2	< 20
BENZO(A)PYRENE	8270-SIM	µg/L	0.2	< 20
BENZO(B)FLUORANTHENE	8270-SIM	µg/L	0.1	< 10
BENZO(G,H,I)PERYLENE	8270-SIM	µg/L	0.1	< 10
BENZO(K)FLUORANTHENE	8270-SIM	µg/L	0.1	< 10
CHRYSENE	8270-SIM	µg/L	0.1	< 10
DIBENZ(A,H)ANTHRACENE	8270-SIM	µg/L	0.1	< 10
FLUORANTHENE	8270-SIM	µg/L	0.1	< 10
FLUORENE	8270-SIM	µg/L	0.1	< 10
INDENO(1,2,3-C,D)PYRENE	8270-SIM	µg/L	0.1	< 10
2-METHYLNAPHTHALENE	8270-SIM	µg/L	0.1	< 10
NAPHTHALENE	8270-SIM	µg/L	0.1	< 10
PHENANTHRENE	8270-SIM	µg/L	0.1	< 10
PYRENE	8270-SIM	µg/L	0.2	< 20
Component Analyzed	Method	Unit	PQL	Analysis Result 0081-081 05-03299-2
MOISTURE	ASTM-D2216	%Moisture	0.5	14
Dilution Factor				10
DIESEL (C10-C24)	8015B	mg/kg	10	760
Dilution Factor				50
SPLP DIESEL (C10-C24)	8015B	mg/L	0.1	72

APCL Analytical Report

Component Analyzed	Method	Unit	PQL	Analysis Result
				0081-081
				05-03299-2
VOLATILE ORGANICS				
Dilution Factor				0.88
ACETONE	8260B	µg/kg	50	48J
BENZENE	8260B	µg/kg	5	<5.1
BROMODICHLOROMETHANE	8260B	µg/kg	5	<5.1
BROMOFORM	8260B	µg/kg	5	<5.1
BROMOMETHANE	8260B	µg/kg	5	<5.1
METHYL ETHYL KETONE (MEK)	8260B	µg/kg	50	<51
CARBON TETRACHLORIDE	8260B	µg/kg	5	<5.1
CHLOROBENZENE	8260B	µg/kg	5	<5.1
CHLORODIBROMOMETHANE	8260B	µg/kg	5	<5.1
CHLOROETHANE	8260B	µg/kg	5	<5.1
CHLOROFORM	8260B	µg/kg	5	<5.1
CHLOROMETHANE	8260B	µg/kg	5	<5.1
1,1-DICHLOROETHANE	8260B	µg/kg	5	<5.1
1,2-DICHLOROETHANE	8260B	µg/kg	5	<5.1
1,1-DICHLOROETHENE	8260B	µg/kg	5	<5.1
CIS-1,2-DICHLOROETHENE	8260B	µg/kg	5	<5.1
TRANS-1,2-DICHLOROETHENE	8260B	µg/kg	5	<5.1
1,2-DICHLOROPROPANE	8260B	µg/kg	5	<5.1
CIS-1,3-DICHLOROPROPENE	8260B	µg/kg	5	<5.1
TRANS-1,3-DICHLOROPROPENE	8260B	µg/kg	5	<5.1
ETHYLBENZENE	8260B	µg/kg	5	<5.1
2-HEXANONE	8260B	µg/kg	50	<51
METHYLENE CHLORIDE	8260B	µg/kg	5	5
4-METHYL-2-PENTANONE (MIBK)	8260B	µg/kg	50	<51
METHYL-T-BUTYL ETHER (MTBE)	8260B	µg/kg	10	<10
STYRENE	8260B	µg/kg	5	<5.1
1,1,2,2-TETRACHLOROETHANE	8260B	µg/kg	5	<5.1
TETRACHLOROETHENE	8260B	µg/kg	5	<5.1
TOLUENE	8260B	µg/kg	5	<5.1
1,1,1-TRICHLOROETHANE	8260B	µg/kg	5	<5.1
1,1,2-TRICHLOROETHANE	8260B	µg/kg	5	<5.1
TRICHLOROETHENE	8260B	µg/kg	5	<5.1
VINYL ACETATE	8260B	µg/kg	50	<51
VINYL CHLORIDE	8260B	µg/kg	5	<5.1
XYLENES (TOTAL)	8260B	µg/kg	15	<15
TERT-BUTYL ALCOHOL (TBA)	8260B	µg/kg	50	<51
DIISOPROPYL ETHER (DIPE)	8260B	µg/kg	5	<5.1
ETHYL TERT-BUTYL ETHER (ETBE)	8260B	µg/kg	5	<5.1
TERT-AMYL METHYL ETHER (TAME)	8260B	µg/kg	5	<5.1

APCL Analytical Report

Component Analyzed	Method	Unit	PQL	Analysis Result 0081-081 05-03299-2
SPLP VOLATILE ORGANICS				
Dilution Factor				1
ACETONE	8260B	µg/L	50	< 50
BENZENE	8260B	µg/L	0.5	< 0.5
BROMODICHLOROMETHANE	8260B	µg/L	5	< 5
BROMOFORM	8260B	µg/L	5	< 5
BROMOMETHANE	8260B	µg/L	5	< 5
METHYL ETHYL KETONE (MEK)	8260B	µg/L	50	< 50
CARBON TETRACHLORIDE	8260B	µg/L	0.5	< 0.5
CHLOROBENZENE	8260B	µg/L	5	< 5
CHLORODIBROMOMETHANE	8260B	µg/L	5	< 5
CHLOROETHANE	8260B	µg/L	5	< 5
CHLOROFORM	8260B	µg/L	5	< 5
CHLOROMETHANE	8260B	µg/L	5	< 5
1,1-DICHLOROETHANE	8260B	µg/L	5	< 5
1,2-DICHLOROETHANE	8260B	µg/L	0.5	< 0.5
1,1-DICHLOROETHENE	8260B	µg/L	5	< 5
CIS-1,2-DICHLOROETHENE	8260B	µg/L	5	< 5
TRANS-1,2-DICHLOROETHENE	8260B	µg/L	5	< 5
1,2-DICHLOROPROPANE	8260B	µg/L	5	< 5
CIS-1,3-DICHLOROPROPENE	8260B	µg/L	0.5	< 0.5
TRANS-1,3-DICHLOROPROPENE	8260B	µg/L	0.5	< 0.5
ETHYLBENZENE	8260B	µg/L	0.5	< 0.5
2-HEXANONE	8260B	µg/L	50	< 50
METHYLENE CHLORIDE	8260B	µg/L	5	1J
4-METHYL-2-PENTANONE (MIBK)	8260B	µg/L	50	< 50
METHYL-T-BUTYL ETHER (MTBE)	8260B	µg/L	1	< 1
STYRENE	8260B	µg/L	5	< 5
1,1,2,2-TETRACHLOROETHANE	8260B	µg/L	1	< 1
TETRACHLOROETHENE	8260B	µg/L	5	< 5
TOLUENE	8260B	µg/L	0.65 (b)	< 0.65
1,1,1-TRICHLOROETHANE	8260B	µg/L	5	< 5
1,1,2-TRICHLOROETHANE	8260B	µg/L	5	< 5
TRICHLOROETHENE	8260B	µg/L	5	> 5
VINYL ACETATE	8260B	µg/L	50	< 50
VINYL CHLORIDE	8260B	µg/L	0.5	< 0.5
XYLENES (TOTAL)	8260B	µg/L	5	< 5
TERT-BUTYL ALCOHOL (TBA)	8260B	µg/L	20	< 20
DIISOPROPYL ETHER (DIPE)	8260B	µg/L	5	< 5
ETHYL TERT-BUTYL ETHER (ETBE)	8260B	µg/L	5	< 5
TERT-AMYL METHYL ETHER (TAME)	8260B	µg/L	5	< 5

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Component Analyzed	Method	Unit	PQL	Analysis Result 0081-081 05-03299-2
PAH				
Dilution Factor				100 (a)
ACENAPHTHENE	8270-SIM	µg/kg	5	< 580
ACENAPHTHYLENE	8270-SIM	µg/kg	5	< 580
ANTHRACENE	8270-SIM	µg/kg	5	< 580
BENZO(A)ANTHRACENE	8270-SIM	µg/kg	5	< 580
BENZO(A)PYRENE	8270-SIM	µg/kg	5	< 580
BENZO(B)FLUORANTHENE	8270-SIM	µg/kg	5	< 580
BENZO(G,H,I)PERYLENE	8270-SIM	µg/kg	5	< 580
BENZO(K)FLUORANTHENE	8270-SIM	µg/kg	5	< 580
CHRYSENE	8270-SIM	µg/kg	5	< 580
FLUORANTHENE	8270-SIM	µg/kg	5	< 580
FLUORENE	8270-SIM	µg/kg	5	< 580
INDENO(1,2,3-C,D)PYRENE	8270-SIM	µg/kg	5	< 580
2-METHYLNAPHTHALENE	8270-SIM	µg/kg	5	< 580
NAPHTHALENE	8270-SIM	µg/kg	5	< 580
PHENANTHRENE	8270-SIM	µg/kg	5	< 580
PYRENE	8270-SIM	µg/kg	5	< 580
SPLP PAH				
Dilution Factor				100
ACENAPHTHENE	8270-SIM	µg/L	0.2	< 20
ACENAPHTHYLENE	8270-SIM	µg/L	0.2	< 20
ANTHRACENE	8270-SIM	µg/L	0.2	< 20
BENZO(A)ANTHRACENE	8270-SIM	µg/L	0.2	< 20
BENZO(A)PYRENE	8270-SIM	µg/L	0.2	< 20
BENZO(B)FLUORANTHENE	8270-SIM	µg/L	0.1	< 10
BENZO(G,H,I)PERYLENE	8270-SIM	µg/L	0.1	< 10
BENZO(K)FLUORANTHENE	8270-SIM	µg/L	0.1	< 10
CHRYSENE	8270-SIM	µg/L	0.1	< 10
DIBENZ(A,H)ANTHRACENE	8270-SIM	µg/L	0.1	< 10
FLUORANTHENE	8270-SIM	µg/L	0.1	< 10
FLUORENE	8270-SIM	µg/L	0.1	< 10
INDENO(1,2,3-C,D)PYRENE	8270-SIM	µg/L	0.1	< 10
2-METHYLNAPHTHALENE	8270-SIM	µg/L	0.1	< 10
NAPHTHALENE	8270-SIM	µg/L	0.1	< 10
PHENANTHRENE	8270-SIM	µg/L	0.1	< 10
PYRENE	8270-SIM	µg/L	0.2	< 20
Component Analyzed	Method	Unit	PQL	Analysis Result 0081-082 05-03299-3
MOISTURE	ASTM-D2216	%Moisture	0.5	19
Dilution Factor				1
DIESEL (C10-C24)	8015B	mg/kg	10	12J
Dilution Factor				1
SPLP DIESEL (C10-C24)	8015B	mg/L	0.1	0.3

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Component Analyzed	Method	Unit	PQL	Analysis Result
				0081-082
				05-03299-3
VOLATILE ORGANICS				
Dilution Factor				0.86
ACETONE	8260B	µg/kg	50	20J
BENZENE	8260B	µg/kg	5	< 5.3
BROMODICHLOROMETHANE	8260B	µg/kg	5	< 5.3
BROMOFORM	8260B	µg/kg	5	< 5.3
BROMOMETHANE	8260B	µg/kg	5	< 5.3
METHYL ETHYL KETONE (MEK)	8260B	µg/kg	50	< 5.3
CARBON TETRACHLORIDE	8260B	µg/kg	5	< 5.3
CHLOROBENZENE	8260B	µg/kg	5	< 5.3
CHLORODIBROMOMETHANE	8260B	µg/kg	5	< 5.3
CHLOROETHANE	8260B	µg/kg	5	< 5.3
CHLOROFORM	8260B	µg/kg	5	< 5.3
CHLOROMETHANE	8260B	µg/kg	5	< 5.3
1,1-DICHLOROETHANE	8260B	µg/kg	5	< 5.3
1,2-DICHLOROETHANE	8260B	µg/kg	5	< 5.3
1,1-DICHLOROETHENE	8260B	µg/kg	5	< 5.3
CIS-1,2-DICHLOROETHENE	8260B	µg/kg	5	< 5.3
TRANS-1,2-DICHLOROETHENE	8260B	µg/kg	5	< 5.3
1,2-DICHLOROPROPANE	8260B	µg/kg	5	< 5.3
CIS-1,3-DICHLOROPROPENE	8260B	µg/kg	5	< 5.3
TRANS-1,3-DICHLOROPROPENE	8260B	µg/kg	5	< 5.3
ETHYLBENZENE	8260B	µg/kg	5	< 5.3
2-HEXANONE	8260B	µg/kg	50	< 5.3
METHYLENE CHLORIDE	8260B	µg/kg	5	5J
4-METHYL-2-PENTANONE (MIBK)	8260B	µg/kg	50	1J
METHYL-T-BUTYL ETHER (MTBE)	8260B	µg/kg	10	< 11
STYRENE	8260B	µg/kg	5	< 5.3
1,1,2,2-TETRACHLOROETHANE	8260B	µg/kg	5	< 5.3
TETRACHLOROETHENE	8260B	µg/kg	5	< 5.3
TOLUENE	8260B	µg/kg	5	< 5.3
1,1,1-TRICHLOROETHANE	8260B	µg/kg	5	< 5.3
1,1,2-TRICHLOROETHANE	8260B	µg/kg	5	< 5.3
TRICHLOROETHENE	8260B	µg/kg	5	< 5.3
VINYL ACETATE	8260B	µg/kg	50	< 5.3
VINYL CHLORIDE	8260B	µg/kg	5	< 5.3
XYLENES (TOTAL)	8260B	µg/kg	15	< 16
TERT-BUTYL ALCOHOL (TBA)	8260B	µg/kg	50	< 5.3
DIISOPROPYL ETHER (DIPE)	8260B	µg/kg	5	< 5.3
ETHYL TERT-BUTYL ETHER (ETBE)	8260B	µg/kg	5	< 5.3
TERT-AMYL METHYL ETHER (TAME)	8260B	µg/kg	5	< 5.3

APCL Analytical Report

Component Analyzed	Method	Unit	PQL	Analysis Result
				0081-082
				05-03299-3
SPLP VOLATILE ORGANICS				
Dilution Factor				1
ACETONE	8260B	µg/L	50	< 50
BENZENE	8260B	µg/L	0.5	< 0.5
BROMODICHLOROMETHANE	8260B	µg/L	5	< 5
BROMOFORM	8260B	µg/L	5	< 5
BROMOMETHANE	8260B	µg/L	5	< 5
METHYL ETHYL KETONE (MEK)	8260B	µg/L	50	< 50
CARBON TETRACHLORIDE	8260B	µg/L	0.5	< 0.5
CHLOROBENZENE	8260B	µg/L	5	< 5
CHLORODIBROMOMETHANE	8260B	µg/L	5	< 5
CHLOROETHANE	8260B	µg/L	5	< 5
CHLOROFORM	8260B	µg/L	5	< 5
CHLOROMETHANE	8260B	µg/L	5	< 5
1,1-DICHLOROETHANE	8260B	µg/L	5	< 5
1,2-DICHLOROETHANE	8260B	µg/L	0.5	< 0.5
1,1-DICHLOROETHENE	8260B	µg/L	5	< 5
CIS-1,2-DICHLOROETHENE	8260B	µg/L	5	< 5
TRANS-1,2-DICHLOROETHENE	8260B	µg/L	5	< 5
1,2-DICHLOROPROPANE	8260B	µg/L	5	< 5
CIS-1,3-DICHLOROPROPENE	8260B	µg/L	0.5	< 0.5
TRANS-1,3-DICHLOROPROPENE	8260B	µg/L	0.5	< 0.5
ETHYLBENZENE	8260B	µg/L	0.5	< 0.5
2-HEXANONE	8260B	µg/L	50	< 50
METHYLENE CHLORIDE	8260B	µg/L	5	2J
4-METHYL-2-PENTANONE (MIBK)	8260B	µg/L	50	< 50
METHYL-T-BUTYL ETHER (MTBE)	8260B	µg/L	1	< 1
STYRENE	8260B	µg/L	5	< 5
1,1,2,2-TETRACHLOROETHANE	8260B	µg/L	1	< 1
TETRACHLOROETHENE	8260B	µg/L	5	< 5
TOLUENE	8260B	µg/L	0.65 ^(b)	< 0.65
1,1,1-TRICHLOROETHANE	8260B	µg/L	5	< 5
1,1,2-TRICHLOROETHANE	8260B	µg/L	5	< 5
TRICHLOROETHENE	8260B	µg/L	5	< 5
VINYL ACETATE	8260B	µg/L	50	< 50
VINYL CHLORIDE	8260B	µg/L	0.5	< 0.5
XYLENES (TOTAL)	8260B	µg/L	5	< 5
TERT-BUTYL ALCOHOL (TBA)	8260B	µg/L	20	< 20
DIISOPROPYL ETHER (DIPE)	8260B	µg/L	5	< 5
ETHYL TERT-BUTYL ETHER (ETBE)	8260B	µg/L	5	< 5
TERT-AMYL METHYL ETHER (TAME)	8260B	µg/L	5	< 5

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APCL Analytical Report

Component Analyzed	Method	Unit	PQL	Analysis Result 0081-082 05-03299-3
PAH				
Dilution Factor				1
ACENAPHTHENE	8270-SIM	µg/kg	5	< 6.2
ACENAPHTHYLENE	8270-SIM	µg/kg	5	< 6.2
ANTHRACENE	8270-SIM	µg/kg	5	< 6.2
BENZO(A)ANTHRACENE	8270-SIM	µg/kg	5	< 6.2
BENZO(A)PYRENE	8270-SIM	µg/kg	5	< 6.2
BENZO(B)FLUORANTHENE	8270-SIM	µg/kg	5	< 6.2
BENZO(G,H,I)PERYLENE	8270-SIM	µg/kg	5	< 6.2
BENZO(K)FLUORANTHENE	8270-SIM	µg/kg	5	< 6.2
CHRYSENE	8270-SIM	µg/kg	5	< 6.2
DIBENZ(A,H)ANTHRACENE	8270-SIM	µg/kg	5	3J
FLUORANTHENE	8270-SIM	µg/kg	5	< 6.2
FLUORENE	8270-SIM	µg/kg	5	< 6.2
INDENO(1,2,3-C,D)PYRENE	8270-SIM	µg/kg	5	< 6.2
2-METHYLNAPHTHALENE	8270-SIM	µg/kg	5	< 6.2
NAPHTHALENE	8270-SIM	µg/kg	5	< 6.2
PHENANTHRENE	8270-SIM	µg/kg	5	< 6.2
PYRENE	8270-SIM	µg/kg	5	< 6.2
SPLP PAH				
Dilution Factor				1
ACENAPHTHENE	8270-SIM	µg/L	0.2	< 0.2
ACENAPHTHYLENE	8270-SIM	µg/L	0.2	< 0.2
ANTHRACENE	8270-SIM	µg/L	0.2	< 0.2
BENZO(A)ANTHRACENE	8270-SIM	µg/L	0.2	< 0.2
BENZO(A)PYRENE	8270-SIM	µg/L	0.2	< 0.2
BENZO(B)FLUORANTHENE	8270-SIM	µg/L	0.1	< 0.1
BENZO(G,H,I)PERYLENE	8270-SIM	µg/L	0.1	< 0.1
BENZO(K)FLUORANTHENE	8270-SIM	µg/L	0.1	< 0.1
CHRYSENE	8270-SIM	µg/L	0.1	< 0.1
DIBENZ(A,H)ANTHRACENE	8270-SIM	µg/L	0.1	< 0.1
FLUORANTHENE	8270-SIM	µg/L	0.1	< 0.1
FLUORENE	8270-SIM	µg/L	0.1	< 0.1
INDENO(1,2,3-C,D)PYRENE	8270-SIM	µg/L	0.1	< 0.1
2-METHYLNAPHTHALENE	8270-SIM	µg/L	0.1	< 0.1
NAPHTHALENE	8270-SIM	µg/L	0.1	< 0.1
PHENANTHRENE	8270-SIM	µg/L	0.1	< 0.1
PYRENE	8270-SIM	µg/L	0.2	< 0.2

PQL: Practical Quantitation Limit. MDL: Method Detection Limit.

CRDL: Contract Required Detection Limit

N.D.: Not Detected or less than the practical quantitation limit.

"-": Analysis is not required.

J: Reported between PQL and MDL.

† All results are reported on dry basis for soil samples.

Listed Dilution Factors (DF) are relative to the method default DF. All unlisted DFs are 1.0

(a) Sample contain high concentration in Fuel Hydrocarbon, dilution was necessary

(b) MDL reported.

Respectfully submitted,


Dorothy Lau
Laboratory Director
Applied P & CH Laboratories

Case Narrative

Project: UST Site 43402/Camp Pendleton/1990.081E

For Tetra Tech FW, Inc.

APCL Service No: 05-3299

1. Sample Identification

The sample identifications are listed in the following table:

Tetra Tech FW, Inc. Sample ID	APCL Sample ID
0081-080	05-03299-1
0081-081	05-03299-2
0081-082	05-03299-3

2. Analytical Methodology

Samples are analyzed by EPA methods

M8015E (TPH: Diesel),

8260B (Volatile organics),

PAH-SIM (PAH),

ASTM-D2216 (Moisture, percent in soil),

3. Holding Time

All samples were extracted, digested and analyzed within the holding times defined by the appropriate EPA methods of the analyses.

4. Preservation

All samples were preserved and stored according to the appropriate EPA methods.

5. Tele-log

Email requesting additional SPLP analyses.

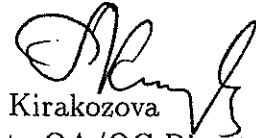
6. Anomaly

(1) SW8270C, SIM, PAH:

All samples and SPLP extracts contained high levels of fuel compounds, and were diluted 100 or 1000 times prior to analyses, in order to reduce matrix interference. Surrogates recoveries in the samples were outside of control limits, they were diluted out.

"I certify that these data are technically accurate, complete, and in compliance with the terms and conditions of the contract, for other than the conditions detailed above. Release of the data contained in the hardcopy data package and its electronic data deliverable submitted on diskette had been authorized by the Laboratory Manager or her/his designee, as verified by the following signature."

Respectfully submitted,

A handwritten signature in black ink, appearing to read 'Regina Kirakozova', written over the printed name.

Regina Kirakozova
Associate QA/QC Director
Applied P & CH Laboratories

LABORATORY ANALYTICAL REPORT

**PROJECT Site 43402/1990081E
Lab Project No. R05G0025**

Report Date: August 11, 2005

Revision 0

Prepared For:

Mark Losi
Tetra Tech
1940 E. Deere Street, Suite 200
Santa Ana, CA 92705
Tel: (949) 756 – 7526
Fax: (949) 756 – 7560

CENTER FOR ENVIRONMENTAL MICROBIOLOGY

555 Technology Court, Suite 100, Riverside, CA 92507
Tel: (951) 788-0808; Fax: (951) 788-8011

August 11, 2005

Project No. 1990081E

Tetra Tech
Attention: Mark Losi
1940 E. Deere Street
Santa Ana, CA 92705

Dear Mark Losi:

This report contains the test results for the soil/groundwater sample(s) from Project No. 1990081E received under chain of custody by the Center for Environmental Microbiology (CEM) on July 6, 2005. These samples are associated with our Laboratory Project No. R05G0025. Test results are based on analyses specified on the analytical report [following page(s)]. The original report for any subcontracted analysis is provided herein.

All applicable quality control procedures met laboratory-specified acceptance criteria. There were no deviations from the laboratory procedures.

This report may only be reproduced in full, with the written approval of CEM. This cover letter is an integral part of the analytical report.

If you have any questions, please feel free to call me at (951) 788-0808, or by e-mail at biocenter@biocem.com.

Sincerely,

William T. Frankenberger, Jr. Ph.D.
Laboratory Director

cc: Project File

CENTER FOR ENVIRONMENTAL MICROBIOLOGY

555 Technology Court, Suite 100, Riverside, CA 92507
Tel: (951) 788-0808; Fax: (951) 788-8011

Analytical Report

Client: Tetra Tech	CEM Project Number: R05G0025
Project: Site 43402/1990081E	Date Sampled: 07/06/2005
Media: Bulk	Date Received: 07/06/2005
Media Type: Soil	Date Analyzed: 07/20/2005
	Analyst: C. Le/ M. Johnson

Client Sample Number (Lab Sample ID)	Analysis	Method	Reporting Limit	Result	Units
0081-080 (R05G0025-1)	Hydrocarbon Oxidizing Microbial Population	Proprietary	3.0×10^1	4.3×10^4	MPN/g
	Total Heterotrophic Plate Count	SM 9215B	3.0×10^2	2.9×10^3	CFU/g
	Orthophosphate – Phosphorous	EPA 365.2	0.2	14.8	mg/Kg
	Ammonium – Nitrogen	EPA 350.2	5.0	< 5.0	mg/Kg
	Nitrate – Nitrogen	84-3.4.3.2 ⁽²⁾	0.5	4.8	mg/Kg
0081-081 (R05G0025-2)	Hydrocarbon Oxidizing Microbial Population	Proprietary	3.0×10^1	9.3×10^1	MPN/g
	Total Heterotrophic Plate Count	SM 9215B	3.0×10^2	3.3×10^3	CFU/g
	Orthophosphate – Phosphorous	EPA 365.2	0.2	5.0	mg/Kg
	Ammonium – Nitrogen	EPA 350.2	5.0	< 5.0	mg/Kg
	Nitrate – Nitrogen	84-3.4.3.2 ⁽²⁾	0.5	4.2	mg/Kg
0081-082 (R05G0025-3)	Hydrocarbon Oxidizing Microbial Population	Proprietary	3.0×10^1	3.6×10^1	MPN/g
	Total Heterotrophic Plate Count	SM 9215B	3.0×10^2	1.8×10^4	CFU/g
	Orthophosphate – Phosphorous	EPA 365.2	0.2	12.4	mg/Kg
	Ammonium – Nitrogen	EPA 350.2	5.0	8.2	mg/Kg
	Nitrate – Nitrogen	84-3.4.3.2 ⁽²⁾	0.5	7.6	mg/Kg

LEGEND

CFU - Colony Forming Units; MPN - Most Probable Number; g - gram; mg - milligrams; Kg - kilogram; mL - milliliters;
N/A - Not applicable; TNTC - Too Numerous to Count; OBSC - Obscured Colonies; RPD - Relative Percent Difference

Notes: ⁽¹⁾Subcontracted analysis

⁽²⁾Methods of Soil Analysis, Chemical and Microbiological Properties, 2nd Edition, 1986. Black. C.A.

These data are intended to be interpreted in conjunction with the information presented in the cover letter of this report.



NUMBER 12419

CHAIN-OF-CUSTODY RECORD

[illegible]

White - Laboratory; Pink - Laboratory; Canary - Project File; Manila - Data Management